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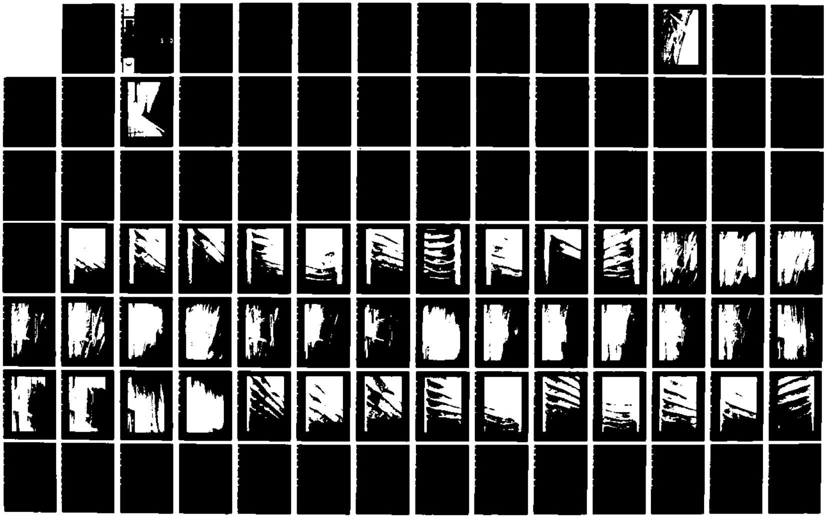

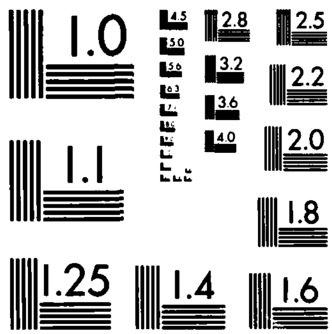
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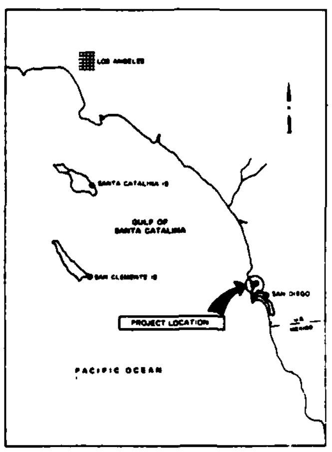

TECHNICAL REPORT CERC-85-11

MISSION BAY HARBOR, SAN DIEGO COUNTY, CALIFORNIA, DESIGN FOR WAVE AND SURGE PROTECTION

Coastal Model Investigation

by

Robert R. Bottin, Jr., Hugh F. Acuff, Jr.

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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Tests were conducted in an existing 1:100-scale model of Mission Bay Harbor to determine the location and orientation of proposed structures for improving hazardous entrance conditions and reducing surge inside the harbor while minimizing impacts on surfing. The model reproduced Mission Bay Harbor, approximately 3 miles of adjacent Pacific Ocean shoreline, and sufficient offshore bathymetry to permit generation of the required test waves. Two wave generators (60 and 70 ft long), special photographic techniques, and an

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20. ABSTRACT (Continued).

automated data acquisition and control system were utilized during model operation. It was concluded from model test results that:

a. Of the improvement plans tested which involved the construction of an offshore breakwater (Plans 10-10D), the 1,050-ft-long structure of Plan 10C was required to meet the established wave-height criteria of 4.0 ft in the entrance for 6-ft incident waves and 1.0 ft in the small-boat basins (Quivira and Mariners Basins) for all wave conditions. The 1,000-ft-long structure of Plan 10B exceeded the criteria in the entrance and small-boat basins by only 0.1 ft and would result in less construction costs and improved navigation.

b. Of the improvement plans tested which involved the construction of a dogleg breakwater and navigation opening toward the north (Plans 11-11C), the 1,330-ft-long structure of Plan 11C was required to meet the established wave-height criteria.

c. The improvement plan tested which involved the construction of a dogleg breakwater and navigation opening toward the south (Plan 12) met the established wave-height criteria.

d. Of all the improvement plans tested (Plans 10-10D, 11-11C, and 12), Plan 10B (1,000-ft-long offshore breakwater) was selected as optimum considering wave protection provided the harbor and entrance, ease of navigation, and economics.

e. The 1,000-ft-long offshore breakwater of Plan 10B will have a minimal impact on surfing conditions at Mission and Ocean Beaches.

f. The 1,000-ft-long offshore breakwater of Plan 10B will result in significantly improved surge conditions due to long-period wave energy in the channel and small-boat basins.

PREFACE

A model investigation of Mission Bay Harbor, California, was initially conducted at the US Army Engineer Waterways Experiment Station (WES) during the period January 1979-March 1982. Test results were reported in WES Technical Report HL-83-17, "Mission Bay Harbor, California, Design for Wave and Surge Protection and Flood Control" (Curren 1983). A request for additional testing of the Mission Bay model was initiated by the District Engineer, US Army Engineer District, Los Angeles (SPL), and subsequently approved by the Office, Chief of Engineers, US Army. Funds for WES to conduct the study were authorized by SPL on 29 January 1985.

The investigation was conducted during the period February-May 1985 by personnel of the Wave Processes Branch (WPB), Wave Dynamics Division (WDD), Coastal Engineering Research Center (CERC), WES, under the direction of Dr. R. W. Whalin, Chief of CERC; Mr. C. C. Calhoun, Assistant Chief of CERC; Mr. C. E. Chatham, Jr., Chief of WDD; and Mr. D. G. Outlaw, Chief of WPB. Tests were conducted by Messrs. H. F. Acuff, Jr., and M. G. Mize, Civil Engineering Technicians, under the supervision of Mr. R. R. Bottin, Jr., Project Manager. This report was prepared by Messrs. Bottin and Acuff and edited by Mrs. Beth F. Vavra, Publications and Graphic Arts Division.

During the course of the investigation, liaison between SPL and WES was maintained by telephone communications and monthly progress reports. The following personnel visited WES to observe model operation and participate in conferences during the course of the model study:

Mr. Tom Pratte	Surfrider Foundation, Pasadena, California
Mr. Hugh Converse	South Pacific Division
Mr. Dee Gonzales	SPL
Mr. Tad Nizinski	SPL
Ms. Lorrie Hanson	SPL
Ms. Deborah Mosser	SPL

COL Allen F. Grum, USA, was Director of WES during the preparation and publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
square feet	0.09290304	square metres
square miles (US statute)	2.589998	square kilometres

MISSION BAY HARBOR, SAN DIEGO COUNTY, CALIFORNIA

DESIGN FOR WAVE AND SURGE PROTECTION

Coastal Model Investigation

PART I: INTRODUCTION

The Prototype

1. Mission Bay is located on the coast of southern California about 10 miles* north of the entrance to San Diego Bay (Figure 1). The complex

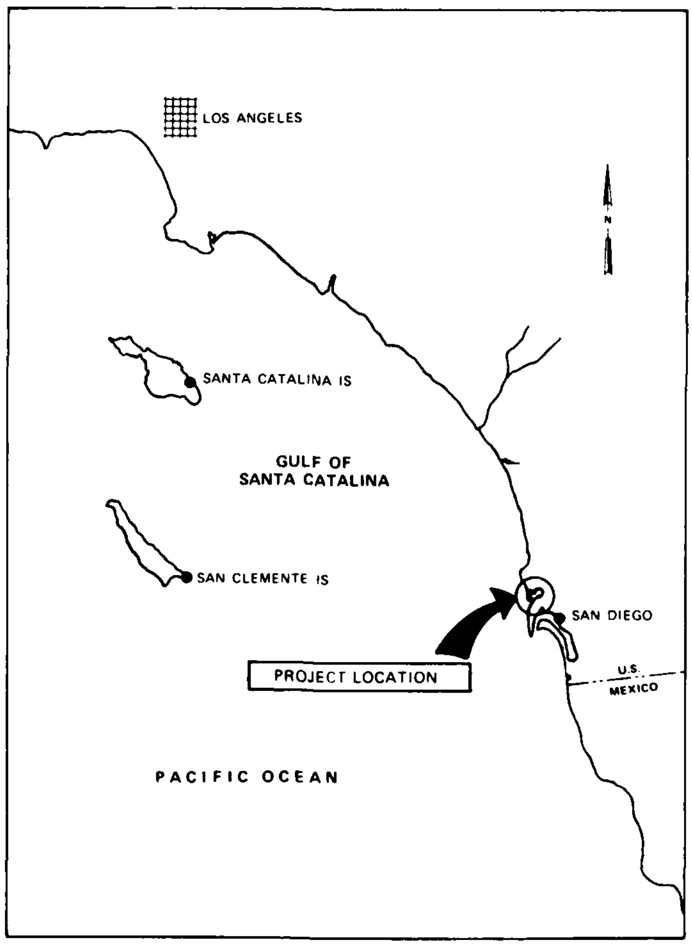

Figure 1. Project location

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

covers an area of approximately 4,000 acres and is very popular for recreational purposes. The San Diego River empties into the Pacific Ocean immediately south of Mission Bay. The existing Federal construction project in Mission Bay and San Diego River was completed in 1959 (USAED, Los Angeles 1984). The entrance to the bay is protected by a 3,300-ft-long north jetty and a 4,270-ft-long middle jetty. The middle jetty also serves to separate the navigation channel from the San Diego River flood-control channel. A 2,050-ft-long south jetty forms the southern border to the San Diego River. Mission Bay is a small-boat harbor as well as an aquatic park providing a wide range of public and private water-oriented recreational facilities. An aerial photograph of Mission Bay is shown in Figure 2.

The Problem

2. Hazardous wave conditions in the harbor entrance channel exist during storms. These waves have resulted in vessels beaching on the rocks, capsizing, sinking, etc. People have been thrown overboard and loss of life has occurred.

3. Excessive surge conditions in the boat basins (Quivira Basin and Mariners Basin) cause damage to boats and facilities inside the harbor. Numerous cracked and sinking floats, broken pilings, worn piling collars, split timbers, and frayed and broken mooring lines can be observed. Water lines and electrical conduits break periodically resulting in service disruptions and large utility bills and repair costs.

4. As a result of littoral transport, a sand plug has developed at the mouth of the San Diego River. The sand plug serves as a beach area and is used extensively for beach recreation. Removal of the sand plug would incur extensive outcries from the public and would not be accepted. However, the sand plug substantially reduces the channel capacity and creates a hazardous flood situation. It is estimated that a standard project flood would result in damages upstream exceeding $5,000,000 (USAED, LA 1984).

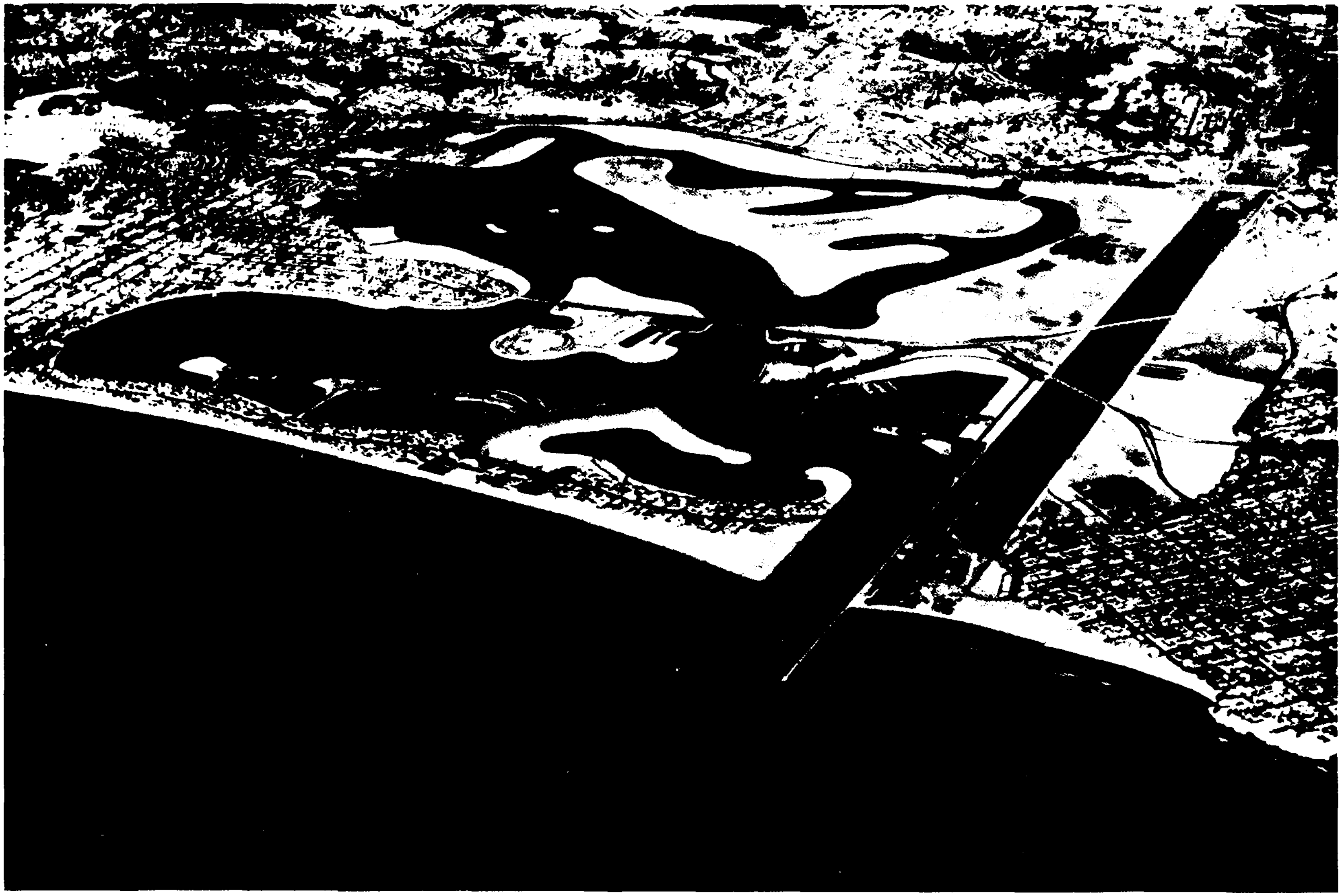

Figure 2. Aerial view of Mission Bay (August 1961)

Previously Reported Model Investigation

5. The Mission Bay model was originally constructed in 1978 to investigate:

   a. Hazardous conditions at the entrance to the harbor due to large short-period (7 to 20 sec) waves.

   b. Surge due to long-period (30 to 140 sec) waves causing damage to boats and facilities inside the harbor.

   c. Potential flood hazards due to a sand plug at the mouth of the San Diego River flood-control channel.

Results of these tests (Curren 1983) indicated that a 1,600-ft-long rubble-mound breakwater installed 525 ft offshore with the concurrent removal of 230 ft from the seaward end of the north jetty would provide safe entrance conditions and reduce surge inside the boat basins. A 1,200-ft-long weir (el +6 ft)* in the middle jetty was required to permit excess San Diego River flows to escape into Mission Bay and minimize flooding upstream.

Purpose of the Present Investigation

6. At the request of the US Army Engineer District, Los Angeles (SPL), the Mission Bay model was reactivated by the US Army Engineer Waterways Experiment Station (WES) to evaluate additional alternative plans at the harbor entrance. The purpose of the investigation was to determine the optimum breakwater configuration at the entrance with respect to wave and surge protection and construction costs, while minimizing impacts on surfing.

Wave-Height Criteria

7. Completely reliable criteria have not yet been developed for ensuring satisfactory navigation and berthing in small-craft harbors. However, for the study reported herein, SPL specified that for an improvement plan to be acceptable, maximum wave heights in the entrance channel behind the breakwater should not exceed 4 ft for deepwater waves of 6 ft or less and maximum wave heights in the basins should not exceed 1.0 ft for all wave conditions.

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* All elevations (el) cited herein are in feet referred to mean lower low water (mllw) unless otherwise stated.

PART II: THE MODEL

Design of the Model

8. The Mission Bay model (Figure 3) was constructed to an undistorted linear scale of 1:100, model to prototype. Scale selection was based on such factors as:

- a. Depth of water required in the model to prevent excessive bottom friction.
- b. Absolute size of model waves.
- c. Available shelter dimensions and area required for model construction.
- d. Efficiency of model operation.
- e. Available wave-generating and wave-measuring equipment.
- f. Model construction costs.

A geometrically undistorted model was necessary to ensure accurate reproduction of short-period wave and current patterns. Following selection of the linear scale, the model was designed and operated in accordance with Froude's model law (ASCE 1942). The scale relations used for design and operation of the model were as follows:

Characteristic	Dimension*	Model:Prototype Scale Relation
Length	L	$L_r = 1:100$
Area	L^2	$A_r = L_r^2 = 1:10,000$
Volume	L^3	$V_r = L_r^3 = 1:1,000,000$
Time	T	$T_r = L_r^{1/2} = 1:10$
Velocity	L/T	$V_r = L_r^{1/2} = 1:10$
Discharge	L^3/T	$Q_r = L_r^{5/2} = 1:100,000$

* Dimensions are in terms of length and time.

9. The proposed improvement plans for Mission Bay included the use of rubble-mound breakwaters and the existing jetties and revetments are also rubble-mound structures. Experience and experimental research have shown that

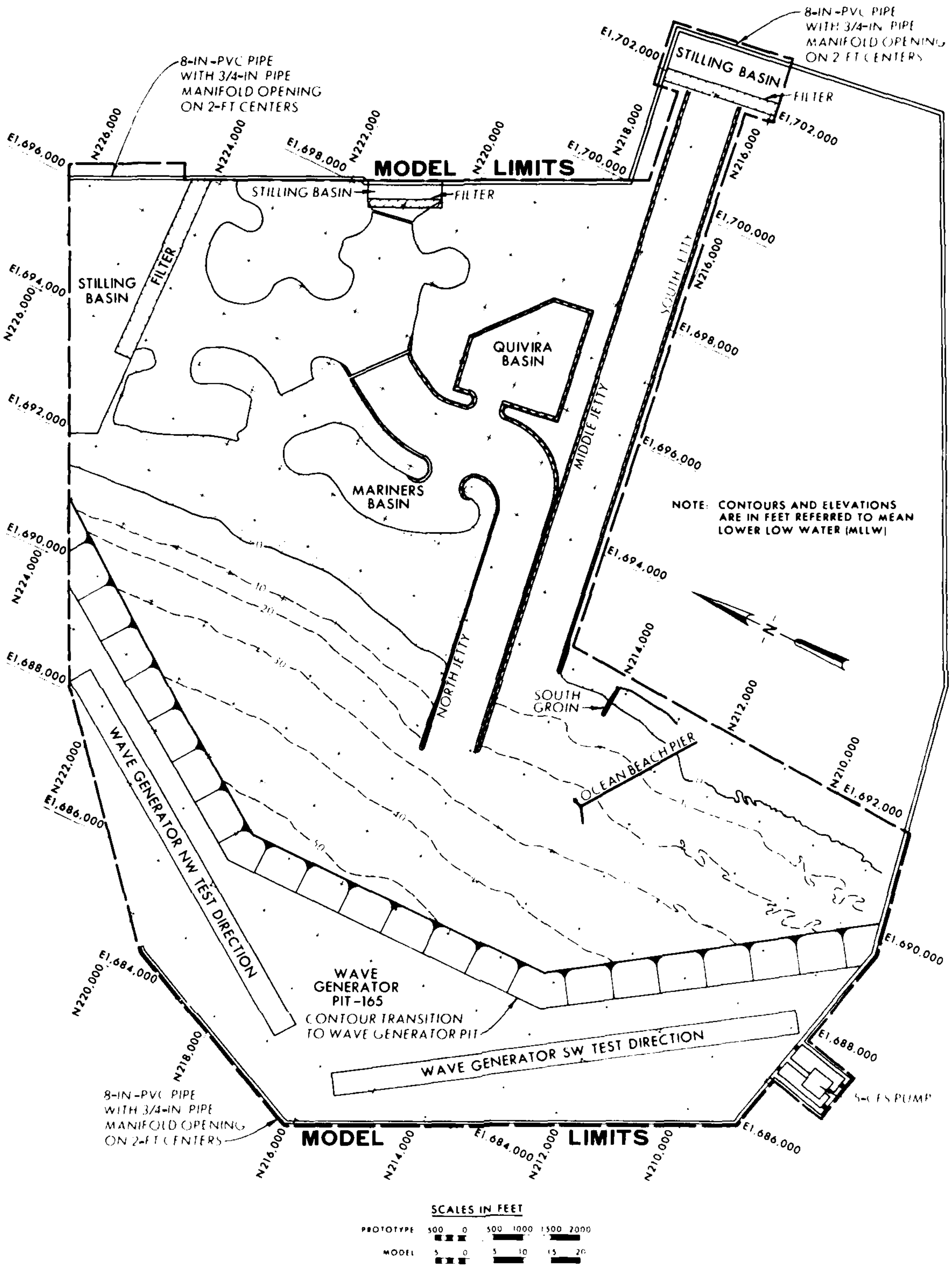

Figure 3. Model layout

considerable wave energy passes through the interstices of this type of structure; thus the transmission and absorption of wave energy became a matter of concern during design of the 1:100-scale model. In small-scale models, rubble-mound structures reflect relatively more and absorb or dissipate relatively less wave energy than geometrically similar prototype structures (LeMehaute 1965). Also, the transmission of wave energy through the structure is relatively less for the small-scale model than for the prototype. Consequently, some adjustment in small-scale rubble-mound structures is needed to ensure satisfactory reproduction of wave-reflection and wave-transmission characteristics. In past investigations at WES (Brasfeild 1965, Dai and Jackson 1966, Ball and Brasfeild 1967), this adjustment was made by determining the wave-energy transmission characteristics of the proposed structure in a two-dimensional model using a scale large enough to ensure negligible scale effects. Therefore, based on previous findings for structures and wave conditions similar to those at Mission Bay, it was determined that a close approximation of the correct wave-energy transmission characteristics could be obtained by increasing the size of the rock used in the 1:100-scale model to approximately 2.0 times that required for geometric similarity. Accordingly, in constructing the rubble-mound structures in the Mission Bay model, rock sizes were computed linearly by scale, then multiplied by 2.0 to determine the actual sizes to be used in the model.

The Model and Appurtenances

10. The model reproduced approximately 3 miles of shoreline and underwater contours to offshore depths ranging from 40 to 54 ft, with a sloping transition to the wave generator pit elevation of -165 ft. The total model area of 17,500 sq ft represented about 6.3 square miles in the prototype. A general view of the model is shown in Figure 4. Vertical control for model construction was based on the mllw elevation of 0.0 ft. Horizontal control was based on a local prototype grid system.

11. Model waves were generated by two wave generators (60 and 70 ft long) each with trapezoidal-shaped, vertical-motion plungers. The vertical motion of each plunger caused a periodic displacement of water incident to the motion. The length of stroke and period of the vertical motion were variable over the range necessary to generate waves with the required characteristics.

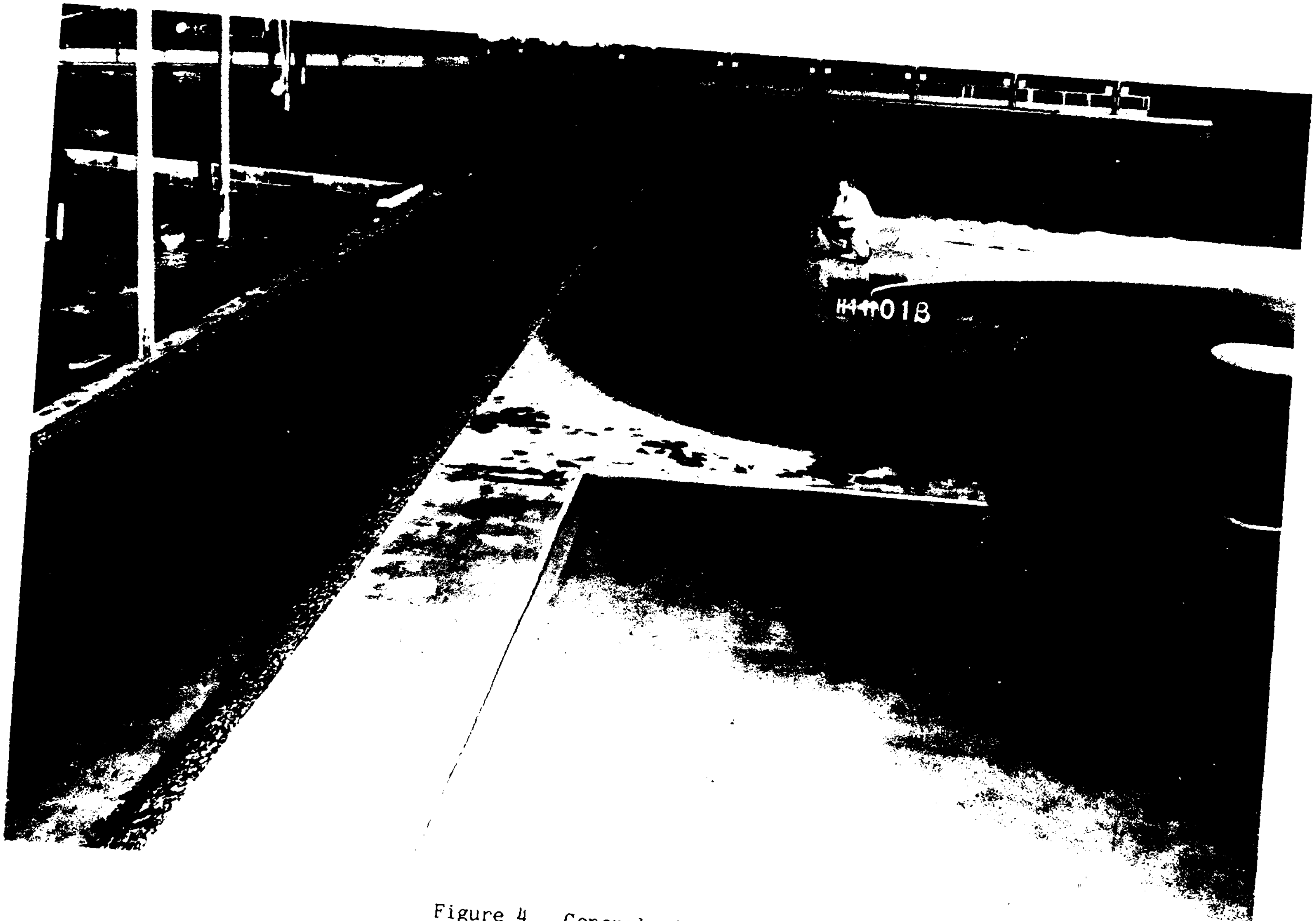

Figure 4. General view of model

In addition, the wave generators were mounted on retractable casters which enabled them to be positioned to generate waves from the required directions.

12. An Automated Data Acquisition and Control System (ADACS), designed and constructed at WES (Figure 5), was used to secure wave-height data at selected locations in the model. Basically, through the use of a minicomputer, ADACS recorded onto magnetic tape the electrical output of parallel-wire resistance-type sensors. These sensors measured the change in water-surface elevation with respect to time. The magnetic tape output of ADACS then was analyzed to obtain the wave-height data.

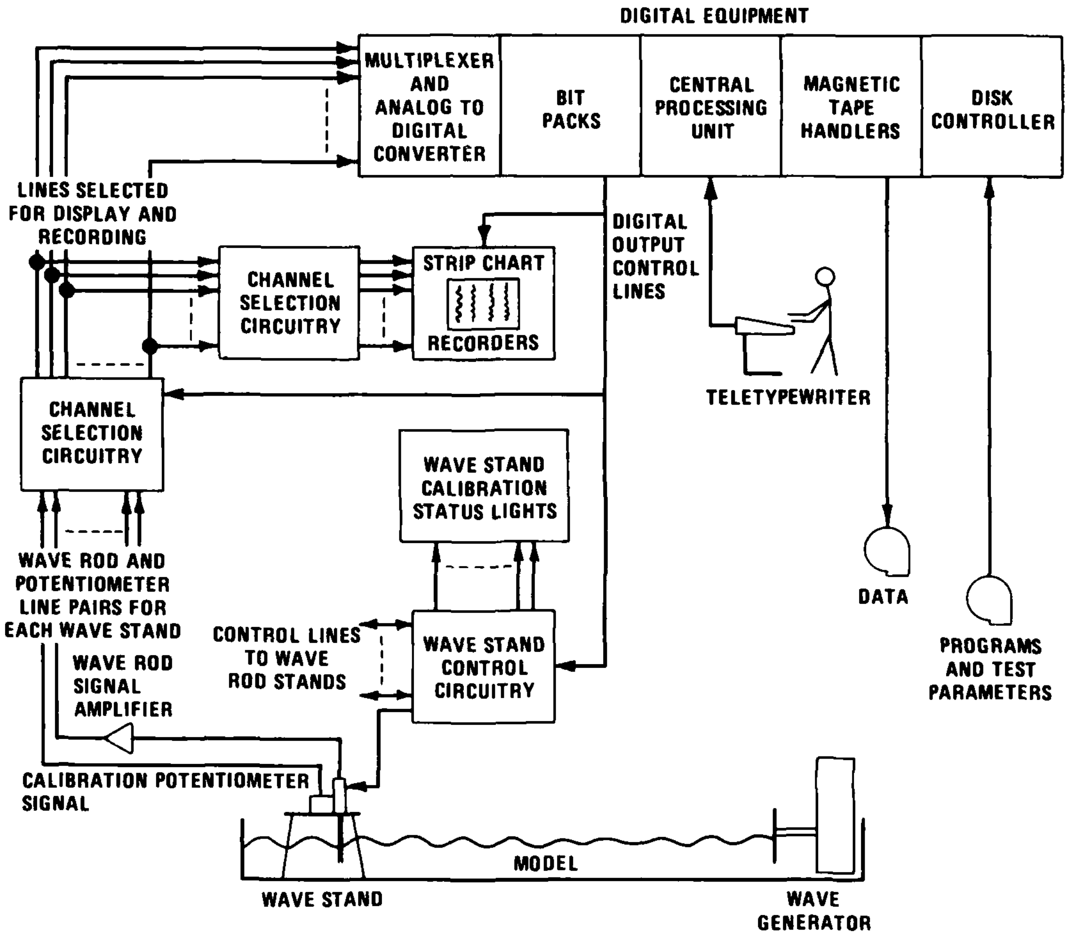

Figure 5. Automated Data Acquisition and Control System (ADACS)

13. A 2-ft (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to damp any wave energy that might otherwise be reflected from the model walls. In addition, guide vanes were placed along the sides of the wave generator to ensure proper formation of the wave train incident to the model contours.

PART III: TEST CONDITIONS AND PROCEDURES

Selection of Still-Water Levels

14. Still-water levels (swl's) for wave-action models are selected so that various wave-induced phenomena that are dependent on water depths are accurately reproduced in the model. These phenomena include refraction of waves as they approach the study area, overtopping of structures by waves, position and strength of longshore currents, reflection of wave energy from structures, and transmission of wave energy through porous structures.

15. In most cases, it is desirable to select a model swl that closely approximates the higher water stages which normally occur in the prototype for the following reasons:

- a. The maximum amount of wave energy reaching a coastal area normally occurs during the higher water phase of the local tidal cycle.
- b. Most storms moving onshore are characteristically accompanied by a higher water level due to wind tide and shoreward mass transport.
- c. The selection of a high swl helps minimize model scale effects due to viscous bottom friction.
- d. When a high swl is selected, a model investigation tends to yield more conservative results.

16. From US Coast and Geodetic Survey records of 1950-1961 (now, National Ocean Survey), the mllw level at Mission Bay is 0.0 ft, and the mean higher high water (mhhw) level is +5.4 ft. The mhhw stage was considered to be a representative water level to be expected during a severe storm and a swl of +5.4 ft was selected for use in the model.

Wave Dimensions and Directions

Factors influencing selection of test-wave characteristics

17. In planning the testing program for a model investigation of wave-action problems, it is necessary to select dimensions and directions for the test waves that will afford a realistic test for the proposed improvement plans and allow an accurate evaluation of the elements of the various proposals. Surface wind waves are generated by the interactions between tangential stresses of wind flowing over water, resonance between the water surface and

atmospheric turbulence, and interactions between individual wave components. The height and period of the maximum wave that can be generated by a given storm depend on the wind speed, the length of time that a wind of a given speed continues to blow (duration), and the water distance (fetch) over which the wind blows. Selection of test wave conditions entails evaluation of such factors as:

- a. Fetch and decay distances (the latter being the distance over which waves travel after leaving the generating area) for the various directions from which waves can attack the problem area.
- b. Frequency of occurrence and duration of storm winds from the different directions.
- c. Alignment and relative geographic position of the study area.
- d. Alignments, lengths, and locations of various structures in the study area.
- e. Refraction of waves caused by differentials in depths in the area seaward of the study area, which may cause either a convergence or a divergence of wave energy.

Wave refraction

18. When wind waves move into water of gradually decreasing depth, transformations take place in all wave characteristics except wave period (to the first order of approximation). The most important transformations with respect to selection of test-wave characteristics are the changes in wave height and direction of travel due to the phenomenon referred to as wave refraction. Changes in wave height and direction can be determined by conducting a wave-refraction analysis. The shoaling coefficient, a function of wavelength and water depth, can be obtained from the Shore Protection Manual (USAEWES, CERC 1984). Thus the refraction coefficient multiplied by the shoaling coefficient gives a conversion factor for transfer of deepwater wave heights to shallow-water values.

19. A wave-refraction analysis conducted by WES was used for deepwater wave directions ranging from 225 to 315 deg and wave periods from 6 to 19 sec. These diagrams represented the propagation of wave fronts from deep water to shallow water (to the point of breaking). By positioning the wave generator to correspond with the wave front at -165 ft (the elevation of the wave-generator pit), the refracted wave from the deepwater direction was accurately reproduced.

Prototype wave data and selection of test waves

20. Estimated durations and magnitudes of deepwater waves approaching Mission Bay, California, were obtained from wave hindcasts by National Marine Consultants (1960) and Marine Advisors (1961) as in a previous Mission Bay model study (Ball and Brasfeild 1969). These data were consolidated into deepwater test directions of northwest, west, and southwest and are summarized in Table 1. Using refraction coefficients from the refraction analysis discussed in paragraph 19 and shoaling coefficients for the water depths at the model wave generator, the deepwater data in Table 1 were converted to shallow-water values and are summarized in Table 2. Test waves used in the model were selected from Table 2 as shown in the following tabulation.

Selected Test Waves and Directions

Deepwater Wave Direction deg	Selected Shallow-Water Wave Test Direction deg	Selected Test Wave Period sec	Selected Test Wave Height ft
Northwest (315)	294	7	6
			9
		9	6
			9
			13
		11	6
			9
			15
		13	6
			11
			17
		15	6
			11
			17
		17	6
			11
			15
		19	6
West (270)	267	7	6
			9
		9	6
			11
		11	6
			13
		13	6
			15
		15	6
			13

(Continued)

Selected Test Waves and Directions (Concluded)

Deepwater Wave Direction deg	Selected Shallow-Water Wave Test Direction deg	Selected Test Wave Period sec	Selected Test Wave Height ft
West (270) (Continued)		17	6
			13
		19	6
Southwest (225)	234	7	6
		9	6
			11
		11	6
			11
		13	6
			11
		15	6
			9
		17	6
		19	6

21. During the course of the investigation, SPL requested that 9-sec, 3-ft, 11-sec, 3-ft, and 13-sec, 3-ft waves from northwest, west, and southwest also be included in the testing program. Specifically, these waves were used for tests in the surfing areas adjacent to the outside of both the north and middle jetties.

Analysis of Model Data

22. The relative merits of the various plans tested were evaluated by a comparison of wave heights at selected locations in the study area and visual observations and photographs. In the wave-height data analysis, the average of the highest one-third of the waves (significant wave height) at each gage location was selected. By using Keulegan's equation (Keulegan 1950), the reduction of wave heights in the model due to bottom friction was calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel; and appropriate corrections were made at each gage location.

PART IV: TESTS AND RESULTS

The Tests

Existing conditions

23. Comprehensive tests were conducted for existing conditions prior to tests of the various improvement plans and were reported in Curren (1983). For this report, however, wave-heights and wave-pattern photographs were obtained only in the surfing areas adjacent to the outside of both the north and middle jetties for existing conditions (Plate 1).

Improvement plans

24. Model tests were conducted for 10 variations in the design elements of 3 basic harbor entrance configurations. The first entrance configuration consisted of an offshore breakwater with two navigation openings. The second configuration entailed a dogleg breakwater with the navigation opening and entrance channel oriented toward the north; and the third involved a dogleg breakwater with the navigation opening and entrance channel oriented toward the south. Variations included changes in the lengths of the various structures. Brief descriptions of the improvement plans are presented in the following subparagraphs; dimensional details are presented in Plates 2-5, and a cross section of the proposed breakwater is shown in Plate 6.

a. Plan 10 (Plate 2) consisted of a 900-ft-long offshore breakwater with a crest elevation of +17.5 ft that was located 525 ft seaward of the jettied entrance. Concurrently, 230 ft of the north jetty was removed to facilitate navigation and water circulation.

b. Plan 10A (Plate 2) entailed the elements of Plan 10 with a 50-ft-long dogleg extension of the northern end of the offshore breakwater resulting in a 950-ft-long structure.

c. Plan 10B (Plates 2 and 3) involved the elements of Plan 10 with a 100-ft-long dogleg extension of the northern end of the offshore breakwater resulting in a 1,000-ft-long structure.

d. Plan 10C (Plate 2) included the elements of Plan 10 with a 150-ft-long dogleg extension of the northern end of the offshore breakwater resulting in a 1,050-ft-long structure.

e. Plan 10D (Plate 2) encompassed the elements of Plan 10 with a 125-ft-long dogleg extension of the northern end of the offshore breakwater resulting in a 1,025-ft-long structure.

f. Plan 11 (Plate 4) consisted of a new 880-ft-long dogleg breakwater which originated at the head of the middle jetty and extended northwesterly and northerly resulting in an entrance

opening toward the north. Also included was the removal of 580 ft of the existing north jetty.

g. Plan 11A (Plate 4) involved the elements of Plan 11 but the new breakwater was increased in length by 150 ft resulting in a 1,030-ft-long structure.

h. Plan 11B (Plate 4) included the elements of Plan 11 but the new breakwater was increased in length by 300 ft resulting in a 1,180-ft-long structure.

i. Plan 11C (Plate 4) included the elements of Plan 11 but the new breakwater was increased in length by 450 ft resulting in a 1,330-ft-long structure.

j. Plan 12 (Plate 5) consisted of a new 1,000-ft-long dogleg breakwater which originated at the head of the north jetty and extended southwesterly and southerly resulting in an entrance opening toward the south.

Short-period wave-height tests

25. Wave-height tests for existing conditions and the various improvement plans were conducted using test waves from one or more of the test directions listed in paragraph 20. As an expedient, tests involving certain proposed improvement plans were limited to one or two critical directions of approach. After the development of a promising plan, wave-height tests were then conducted from the remaining directions of approach to assure that the specified wave-height criteria were met for all wave conditions. The wave gage locations for existing conditions and each improvement plan are shown in the referenced plates.

Long-period wave tests

26. Long-period (30 to 140 sec) wave tests were conducted for the most promising breakwater plan (with respect to short-period wave protection) using waves from the west test direction. Wave gage locations for long-period wave tests are shown in Plate 3. The two types of tests involved with investigating long-period waves are as follows:

a. Frequency response tests involved the placement of wave sensors at strategic locations throughout the harbor to measure the amplitude of oscillations (Plates 7-20). An array of 12 wave gages at the harbor entrance was used to determine the amplitude of incident waves. By plotting the ratio of the measured wave height at each gage to the incident wave height (response factor) versus the wave periods tested, frequency response curves showing resonant peaks were obtained.

b. Surface-float tests were conducted using small white squares of Styrofoam "confetti" and time-lapse photography to determine oscillation patterns. The confetti was spread over the surface

of the channel and basins and subsequent movement by each wave period was photographed by a series of overhead cameras with shutter openings equal to the wave period being tested. The resulting mosaics show the oscillation patterns and location of nodes and antinodes.

Test Results

27. In evaluating test results, the relative merits of various plans were based primarily on an analysis of measured wave heights at the entrance and inner basins and frequency response of the inner basins. Test results of the various plans were compared with those for existing conditions (as reported in Curren (1983)). Model wave heights (significant wave heights) were tabulated to show measured values at selected locations. Frequency-response curves were plotted graphically to depict wave-height amplification factors at various locations throughout the harbor.

Existing conditions

28. Results of wave-height tests conducted for existing conditions in the surfing areas are shown in Table 3. Maximum wave heights were 15.7 ft along Mission Beach (gage 15) for 17-sec, 11-ft test waves from northwest; and 13.4 ft along Ocean Beach (gage 16) for 15-sec, 6-ft test waves from southwest. Caution should be exercised when evaluating these wave-height data since the gages were located in the breaker zone. In some cases, the smaller test waves (6 ft or less) were breaking in the surfing area directly on a wave gage whereas the larger test waves broke seaward and re-formed in the surfing area. Wave energy reflected off the jetties (particularly for test waves from the northwest) and coinciding with the incident wave train also increased wave heights substantially. Typical wave patterns obtained in the surfing areas for representative test waves for existing conditions are shown in Photos 1-10.

Improvement plans

29. Results of wave-height tests conducted for Plan 10 for test waves from northwest are presented in Table 4. For 6-ft incident test waves, maximum wave heights in the entrance (gage 1) were 4.8 ft. Considering all test conditions, maximum wave heights were 1.3 ft in Quivira Basin (gage 5) for 17-sec, 15-ft test waves; and 1.1 ft in Mariners Basin (gage 13) for 15-sec, 11-ft test waves. Typical wave patterns for Plan 10 are shown in Photos 11 and 12.

30. Wave heights secured for Plans 10A-10D for representative test waves from northwest are presented in Table 5. With 6-ft incident test waves, maximum wave heights in the entrance (gage 1) were 4.2, 4.1, 3.4, and 4.0 ft, respectively, for Plans 10A-10D. Considering the larger test waves, maximum wave heights were 1.1, 1.1, 1.0, and 1.1 ft in Quivira Basin (gage 6); and 1.0, 1.1, 0.9, and 1.0 ft in Mariners Basin (gage 13) for Plans 10A-10D, respectively. Typical wave patterns for Plans 10A-10D for representative test waves from northwest are shown in Photos 13-20.

31. Wave-height tests conducted for Plan 10C for test waves from southwest are presented in Table 6. For 6-ft incident wave conditions, maximum wave heights were 3.2 ft in the entrance (gage 1) for 19-sec, 6-ft test waves. Considering all test waves, maximum wave heights were 0.7 ft in Quivira Basin (gages 5 and 6) for 13-sec, 11-ft test waves; and 0.9 ft in Mariners Basin (gage 13) for 11-sec, 11-ft test waves. Representative wave patterns for Plan 10C for test waves from southwest are shown in Photo 21.

32. Wave heights secured for Plans 11-11C are presented in Table 7 for test waves from northwest. For 19-sec, 6-ft test waves, maximum wave heights in the entrance (gage 1) were 6.3, 5.6, 5.0, and 3.8 ft for Plans 11-11C, respectively. For 17-sec, 15-ft test waves, maximum wave heights were 0.7 ft in both Quivira and Mariners Basins. Typical wave patterns for Plans 11-11C are shown in Photos 22-26 for test waves from northwest.

33. Results of wave-height tests obtained with Plan 12 installed are shown in Table 8 for test waves from southwest. For 6-ft incident waves, maximum wave heights in the entrance (gage 1) were 2.7 ft for 17-sec, 6-ft test waves. Considering all the test waves, maximum wave heights were 0.7 ft in Quivira Basin (gage 5) for 13-sec, 11-ft test waves; and 0.7 ft in Mariners Basin (gage 13) for 11-sec, 11-ft and 9-sec, 11-ft test waves. Typical wave patterns for Plan 12 are shown in Photo 27.

34. At the request of SPL, Plan 10B was reinstalled in the model and comprehensive tests were conducted for test waves from northwest, west, and southwest. Results of these tests are shown in Table 9. For 6-ft incident test waves, maximum wave heights in the entrance (gage 1) were 4.1 ft for 19-sec, 6-ft test waves from northwest. For all test waves, maximum wave heights were 1.1 ft in Quivira Basin (gage 6) and 1.1 ft in Mariners Basin (gage 13) both for 17-sec, 15-ft test waves from northwest. Typical wave patterns for Plan 10B are shown in Photos 28-31 for test waves from west and southwest.

35. Results of wave-height tests conducted for Plan 10B in the surfing areas are shown in Table 10. Maximum wave heights were 16.2 ft along Mission Beach (gage 15) for 17-sec, 15-ft test waves from northwest; and 12.4 ft along Ocean Beach (gage 16) for 15-sec, 9-ft test waves from southwest. Since the gages were located in the breaker zone, caution should be exercised in evaluation of these wave-height data. In some instances, the smaller test waves (6 ft or less) were breaking in the surfing area directly on a wave gage whereas the larger test waves broke seaward and re-formed in the surfing area. Wave energy reflected off the jetties (particularly for test waves from the northwest) and coinciding with the incident wave train also increased wave heights substantially. Typical wave patterns obtained in the surfing areas for representative test waves for Plan 10B are shown in Photos 32-41.

36. Long-period wave test results for Plan 10B indicate that the offshore breakwater reduces response in the entrance channel at gages 13 and 14 (Plates 7 and 8) when compared with existing conditions. The widths of the peak responses also were decreased which reduces the frequency of occurrence that waves may cause oscillations. Peak responses in Quivira Basin (gages 15-22) were reduced significantly (Plates 9-16) in most cases as opposed to those obtained for existing conditions. In some cases, peaks shifted slightly but, in general, occurred at similar periods. Peak responses in Mariners Basin (gages 23-26) also were reduced significantly (Plates 17-20) in most cases. When compared with existing conditions, peaks occurred at similar periods, and the widths of the peak responses were reduced. In general, harbor oscillation conditions were much less in Mission Bay for Plan 10B than for existing conditions. Magnitudes of resonant peaks were reduced by up to 50 percent in Quivira Basin and by greater than 50 percent in some cases in Mariners Basin.

Discussion of test results

37. Results of wave-height tests for the initial 900-ft-long offshore breakwater (Plan 10) indicated 4.8-ft wave heights in the entrance for 19-sec, 6-ft test waves from northwest. Other 6-ft incident waves (ranging from 7 to 17 sec) resulted in wave heights below the established 4.0-ft wave-height criterion at the entrance. Several test waves, however, resulted in wave heights in excess of the 1.0-ft wave-height criterion established in the small-boat basins (Quivira and Mariners Basins).

38. Test results for various extensions to the north end of the offshore breakwater revealed improved wave conditions in the entrance and

small-boat basins for test waves from northwest. The 150-ft-long extension of Plan 10D resulted in 3.4-ft wave heights in the entrance (well within the established 4.0-ft criterion) for 6-ft incident waves. Plan 10D also met the 1.0-ft wave-height criterion in the small-boat basins for all test waves. The 125-ft-long extension of Plan 10C met the 4.0-ft criterion in the entrance, but exceeded the 1.0-ft criterion in the small-boat basins by 0.1 ft. The 100-ft-long extension of Plan 10B exceeded both the 4.0-ft criterion in the entrance and the 1.0-ft criterion in the small-boat basins by 0.1 ft each. The 50-ft extension of Plan 10A resulted in 4.2-ft wave heights in the entrance (0.2 ft in excess of the criterion) and 1.1-ft wave heights in the small-boat basins (0.1 ft in excess of the criterion). Although Plans 10A and 10B resulted in wave heights that exceeded the 4.0-ft criterion in the entrance (by 0.2 and 0.1 ft, respectively), the duration of the 19-sec, 6-ft incident waves that produced these results is only 4 hr/yr. Also, the 17-sec, 15-ft incident waves that produced the 1.1-ft wave heights in the small-boat basins for Plans 10A-10C only occur 2 hr/yr. Considering these frequencies of occurrence, construction costs, and ease of navigation through the north entrance, Plan 10B (1,000-ft-long breakwater) was considered the optimum offshore improvement plan. Subsequent tests indicated that test waves from west and southwest resulted in wave heights within the established criteria.

39. Results of wave-height tests, which included a dogleg breakwater and navigation opening toward the north (Plans 11-11C), indicated that a 1,330-ft-long breakwater (Plan 11C) would be required to obtain the desired wave-height criterion of 4.0 ft in the entrance for waves from northwest. Based on the length of structure required, Plan 11C was not considered a viable alternative.

40. Wave-height tests for the dogleg breakwater and navigation opening toward the south (Plan 12) indicated that the original 1,000-ft-long breakwater met the wave-height criteria in both the entrance and the small-boat basins. This plan, however, limited boaters to only one entrance.

41. An evaluation of the data for short-period wave tests, considering all the plans tested, resulted in the 1,000-ft-long offshore breakwater of Plan 10B being selected as the most promising plan with respect to wave protection, construction costs, and ease of navigation. The wave-height criteria will be exceeded by 0.1 ft for only a few hours a year. The Plan 10B offshore breakwater also will afford boaters the opportunity of using two entrances.

They can enter and leave the harbor from the north or south depending on the direction of wave approach. Therefore Plan 10B was selected for more detailed testing.

42. A comparison of wave heights obtained in the surfing areas adjacent to the north and middle jetties for existing conditions and Plan 10B revealed that the offshore structure would have a minimal impact on surfing conditions. Wave heights and wave patterns at Mission Beach were similar for test waves from northwest, and wave heights and wave patterns at Ocean Beach were similar for test waves from southwest. Wave-height tests and wave pattern photographs for both Mission Beach and Ocean Beach also yielded similar results for test waves from west.

43. A comparison of long-period wave test results for existing conditions and Plan 10B indicates that the breakwater effectively reduced long-period wave energy in the entrance channel and mooring basins. In most cases, response peaks were reduced in both magnitude and width. The breakwater of Plan 10B should result in significantly improved long-period wave conditions at Mission Bay.

PART V: CONCLUSIONS

44. Based on the results of the hydraulic model investigation reported herein, it is concluded that:

a. Of the improvement plans tested which involved the construction of an offshore breakwater (Plans 10-10D), the 1,050-ft-long structure of Plan 10C was required to meet the established wave-height criteria of 4.0 ft in the entrance for 6-ft incident waves and 1.0 ft in the small-boat basins (Quivira and Mariners Basins) for all wave conditions. The 1,000-ft-long structure of Plan 10B exceeded the criteria in the entrance and small-boat basins by only 0.1 ft and would result in less construction costs and improved navigation.

b. Of the improvement plans tested which involved the construction of a dogleg breakwater and navigation opening toward the north (Plans 11-11C), the 1,330-ft-long structure of Plan 11C was required to meet the established wave-height criteria.

c. The improvement plan tested which involved the construction of a dogleg breakwater and navigation opening toward the south (Plan 12) met the established wave-height criteria.

d. Of all the improvement plans tested (Plans 10-10D, 11-11C, and 12), Plan 10B (1,000-ft-long offshore breakwater) was selected as optimum considering wave protection provided the harbor and entrance, ease of navigation, and economics.

e. The 1,000-ft-long offshore breakwater of Plan 10B will have a minimal impact on surfing conditions at Mission and Ocean Beaches.

f. The 1,000-ft-long offshore breakwater of Plan 10B will result in significantly improved surge conditions due to long-period wave energy in the channel and small-boat basins.

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Table 1

Estimated Duration and Magnitude of Deepwater Waves Approaching Mission Bay from Various Directions

Wave Height ft	Duration, hr/yr, for Wave Periods* of, sec								
	<4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20
					Northwest				
0-1									
1-2	254	503	20	1,080	792	140	50	11	6
2-3		761	251	899	597	136	124	65	14
3-4		260	464	601	247	127	63	51	12
4-5		62	749	260	171	122	69	26	4
5-6			406	200	131	67	17	8	
6-7			156	197	111	37	23	6	
7-9			32	657	76	49	15	2	
9-11				176	77	15	6		
11-13				20	56	2			
13-15				4	21	2			
15-17					2		2		
					West				
0-1		9	158	614	885	701	307	96	26
1-2	228	88	157	61	149	324	491	254	88
2-3		96	147	225	93	59	35	96	105
3-4		53	43	94	62	31	2	8	44
4-5		26	41	42	20	9	11	2	18
5-6		6	20	25	28	12	9	4	
6-7				27	28	11	6		
7-9			9	25	28	18	2		
9-11				2	20	14	9		
11-13					15	2	61	2	
13-15						8			
					Southwest				
0-1			9	35	18	745	720	150	35
1-2	221	140	44	55	71	1,586	1,113	316	53
2-3		138	41	15	28	527	420	114	9
3-4		45	55	19	4	79	123	124	9
4-5		9	43	9	2	9	26	9	9
5-6			15	9	9			18	
6-7			8	6					9
7-9				17	11		18		
9-11				2	4				

Note: Since two or more well-developed wave trains may exist simultaneously, the total duration for a given period may exceed 100 percent.

* Wave-height and wave-period groupings include the lower but not the upper values.

Table 2

Estimated Duration and Magnitude of Shallow-Water Waves Approaching Mission Bay from Various Directions

Wave Height ft	Duration, hr/yr, for Wave Periods* of, sec <4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20
					Northwest				
0-1									
1-2	254	503	20	1,082	792				
2-3		761	251	899	597	140	50		6
3-4		260	464	628	247	136	124	11	14
4-5		62	749	259	171	127	63	65	12
5-6			406	326	131	122	69		4
6-7			156	674	111	67	17	51	
7-9			32	207	129	37	23	26	
9-11				34	99	49	15	14	
11-13				6	2	15	6		
13-15					2	2		2	
15-17						2			
17-19							2		
					West				
0-1		9	158	614	885	701	307	96	26
1-2	228	88	157	61	149	324	491	254	88
2-3		96	147	225	93	59	35	96	105
3-4		53	43	94	62	31	2	8	44
4-5		26	41	42	20	9	11	2	18
5-6		6	20	25	28	12	9	4	
6-7				27	28	11	6		
7-9			9	25	28	18	2		
9-11				2	20	14	9		
11-13					15	2	61	2	
13-15						8			
					Southwest				
0-1			9	35	18	745	720	150	35
1-2	220	140	55	55	71	1,665	1,174	334	53
2-3		138	40	17	32	448	359	105	9
3-4		45	81	17	2	79	123	115	9
4-5		9	31	11		9	26	9	9
5-6			6	9	9			18	
6-7			6	6					9
7-9				19	11		18		
9-11					4				

Note: Since two or more well-developed wave trains may exist simultaneously, the total duration for a given period may exceed 100 percent.

* Wave-height and wave-period groupings include the lower but not the upper values.

Table 3
Wave Heights in Surfing Areas for Existing Conditions

Test Wave Period sec	Test Wave Height ft	Northwest Gage 15	Northwest Gage 16	West Gage 15	West Gage 16	Southwest Gage 15	Southwest Gage 16
7	6	7.9	2.4	7.6	3.9	2.3	5.2
	9	12.6	3.2	9.7	6.0	--	--
9	3	3.3	1.5	3.7	1.1	1.2	2.8
	6	8.5	3.8	8.6	3.0	2.5	8.2
	9	12.8	4.9	--	--	--	--
	11	--	--	12.1	9.5	7.1	11.0
	13	8.7	7.8	--	--	--	--
11	3	8.0	1.3	3.8	0.8	1.1	2.5
	6	14.6	2.9	7.6	2.8	2.5	3.7
	9	12.6	5.2	--	--	--	--
	11	--	--	--	--	9.0	11.8
	13	--	--	10.0	8.9	--	--
	15	13.7	9.9	--	--	--	--
13	3	9.5	1.7	3.5	1.5	1.1	1.4
	6	13.1	5.1	9.4	4.0	3.3	9.7
	11	12.7	12.5	--	--	9.2	10.0
	13	--	--	--	--	--	--
	15	--	--	10.4	10.8	--	--
	17	11.8	11.6	--	--	--	--
15	6	11.6	7.1	9.5	7.6	4.9	13.4
	9	--	--	--	--	8.8	11.6
	11	13.0	10.3	--	--	--	--
	13	--	--	11.8	9.9	--	--
	17	13.1	11.9	--	--	--	--
17	6	13.6	6.6	12.0	11.2	6.6	12.2
	11	15.7	10.7	--	--	--	--
	13	--	--	8.3	11.7	--	--
	15	13.6	9.6	--	--	--	--
19	6	11.1	9.9	14.6	11.5	6.0	12.5

(Wave Height, ft, at Indicated Direction and Gage Locations)

Table 4

Wave Heights for Plan 10 for Test Waves from Northwest

Test Wave		Wave Height, ft, at Indicated Gage Locations													
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
7	6	2.8	1.4	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	2.4	0.1	0.1	5.2
	9	3.4	1.6	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	3.2	0.1	0.1	7.6
9	6	3.7	0.7	0.5	0.3	0.1	0.2	0.2	0.2	0.2	0.1	2.4	0.3	0.3	5.8
	9	4.6	0.6	0.6	0.3	0.1	0.3	0.2	0.3	0.3	0.2	3.4	0.4	0.4	9.0
	13	5.9	1.0	1.0	0.3	0.1	0.3	0.2	0.3	0.4	0.2	4.7	0.6	0.6	15.0
11	6	2.8	1.3	0.8	0.2	0.1	0.2	0.2	0.4	0.3	0.3	3.4	0.2	0.3	5.1
	9	4.8	2.2	1.3	0.5	0.2	0.3	0.3	0.7	0.4	0.6	4.7	0.5	0.7	9.3
	15	9.6	3.5	2.3	0.7	0.3	0.5	0.4	0.6	0.3	0.8	8.7	0.9	0.8	19.1
13	6	2.1	1.7	0.9	0.3	0.4	0.4	0.4	0.3	0.1	0.1	4.2	0.3	0.2	6.7
	11	6.6	2.4	0.8	0.5	0.5	0.4	0.4	0.5	0.4	0.4	7.2	0.3	0.3	14.3
	17	9.7	5.2	2.0	0.7	1.2	0.9	0.9	1.0	0.4	0.5	8.3	1.0	0.8	16.6
15	6	2.9	2.7	1.7	0.4	0.2	0.2	0.4	0.2	0.1	0.1	3.9	0.9	0.7	6.1
	11	4.3	3.8	2.2	1.0	0.5	0.3	0.7	0.5	0.2	0.4	7.3	1.0	1.1	14.0
	17	12.4	4.8	3.0	1.1	0.8	0.8	0.8	0.8	0.5	0.5	9.3	1.0	0.9	15.5
17	6	3.2	2.7	1.1	1.0	0.7	0.4	0.5	0.4	0.4	0.2	3.3	0.7	0.5	6.7
	11	6.7	4.4	2.0	1.7	1.2	0.8	0.8	0.7	0.6	0.3	5.6	1.3	0.8	12.0
	15	12.5	5.6	2.2	2.2	1.3	1.0	0.9	1.2	0.4	0.5	6.9	1.2	0.7	15.3
19	6	4.8	2.6	1.3	0.6	0.4	0.6	0.4	1.1	0.7	0.4	2.8	1.2	0.4	6.3

Table 5

Wave Heights for Plans 10A-10D for Test Waves from Northwest

Test Wave		Wave Height, ft, at Indicated Gage Locations													
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
							Plan 10A								
13	17	11.4	4.1	1.8	0.7	0.9	0.6	0.6	0.7	0.5	0.5	9.1	1.0	0.7	15.7
15	11	3.7	3.7	1.9	0.6	0.3	0.3	0.4	0.4	0.2	0.2	7.8	1.1	0.9	12.1
17	11	6.1	3.8	1.8	1.5	0.9	0.9	0.6	0.5	0.4	0.3	6.4	1.4	0.6	12.5
	15	12.3	4.4	1.7	2.0	0.9	1.1	1.0	0.9	0.5	0.5	8.5	1.7	1.0	16.0
19	6	4.2	2.5	1.1	0.6	0.4	0.6	0.3	1.0	0.7	0.4	2.8	1.1	0.4	5.7
							Plan 10B								
13	17	10.0	4.0	1.5	0.6	0.7	0.5	0.5	0.5	0.4	0.4	8.2	0.8	0.4	14.2
15	11	3.6	3.3	1.6	0.6	0.5	0.4	0.4	0.4	0.3	0.6	7.7	0.9	0.8	10.9
17	11	6.2	4.0	1.7	1.4	1.0	0.9	0.7	0.6	0.5	0.3	7.0	1.5	0.5	11.8
	15	11.5	4.2	1.7	2.2	1.0	1.1	1.0	0.9	0.5	0.4	8.0	1.7	1.1	14.6
19	6	4.1	2.3	0.9	0.4	0.3	0.5	0.5	1.0	0.5	0.3	3.1	1.2	0.5	5.9
							Plan 10C								
13	17	9.0	3.5	1.6	0.4	0.5	0.5	0.4	0.5	0.3	0.4	8.6	0.6	0.4	16.8
15	11	2.9	3.5	1.7	0.5	0.2	0.3	0.4	0.3	0.2	0.2	7.1	0.9	0.9	13.7
17	11	4.1	3.7	1.6	1.4	0.9	0.6	0.6	0.7	0.2	0.2	6.4	0.6	0.7	10.4
	15	10.6	4.5	1.7	2.2	0.9	1.0	0.8	0.9	0.5	0.4	8.3	1.6	0.7	13.9
19	6	3.4	2.0	0.6	0.3	0.2	0.3	0.5	0.8	0.3	0.2	3.5	0.9	0.3	5.0
							Plan 10D								
13	17	8.7	4.5	2.0	0.6	0.9	0.8	0.6	0.7	0.5	0.5	9.9	1.0	0.8	18.2
15	11	3.2	3.3	1.9	0.7	0.4	0.4	0.6	0.4	0.2	0.3	7.1	0.8	1.0	15.1
17	11	5.6	4.1	1.8	1.3	1.0	0.7	0.5	0.9	0.3	0.3	6.5	0.8	0.9	12.5
	15	10.7	4.3	1.7	2.3	0.9	1.1	1.0	1.0	0.5	0.4	8.1	1.6	0.9	14.0
19	6	4.0	2.7	0.9	0.6	0.3	0.5	0.6	0.4	0.3	0.3	3.6	0.9	0.5	7.4

Table 6

Wave Heights for Plan 10C for Test Waves from Southwest

Test Wave Period sec	Test Wave Height ft	Wave Height, ft, at Indicated Gage Locations: Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
7	6	1.3	1.0	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	4.5	0.1	0.2	2.2
9	6	1.1	1.2	1.0	0.2	0.1	0.2	0.3	0.3	0.2	0.2	4.1	0.3	0.3	3.1
	11	3.3	1.0	0.8	0.3	0.3	0.5	0.3	0.3	0.6	0.3	8.6	0.4	0.3	4.9
11	6	1.4	1.6	1.1	0.3	0.3	0.2	0.2	0.3	0.3	0.3	3.5	0.3	0.5	3.6
	11	4.8	1.8	1.4	0.5	0.3	0.4	0.4	0.6	0.4	0.5	12.1	0.7	0.9	6.6
13	6	1.7	1.1	0.4	0.1	0.3	0.3	0.2	0.3	0.1	0.2	3.4	0.1	0.1	4.7
	11	6.3	2.7	1.4	0.4	0.7	0.7	0.6	0.5	0.3	0.4	14.4	0.4	0.4	7.3
15	6	1.9	1.5	1.1	0.4	0.3	0.3	0.5	0.3	0.2	0.3	4.8	0.8	0.5	4.5
	9	4.2	2.1	0.8	0.4	0.3	0.4	0.3	0.3	0.2	0.2	13.8	0.4	0.4	6.9
17	6	3.1	1.5	0.6	0.6	0.4	0.2	0.2	0.2	0.2	0.1	4.3	0.4	0.2	4.9
19	6	3.2	1.5	0.5	0.2	0.2	0.2	0.5	0.4	0.3	0.2	5.8	0.5	0.4	3.4

Table 7

Wave Heights for Plans 11-11C for Test Waves from Northwest

Test Wave		Wave Height, ft, at Indicated Gage Locations													
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
Plan 11															
19	6	6.3	4.5	1.5	0.9	0.7	0.8	0.8	1.6	0.8	0.7	--	1.7	0.8	11.3
Plan 11A															
19	6	5.6	3.3	1.1	0.5	0.5	0.8	0.4	0.9	0.6	0.6	--	1.7	0.6	8.7
Plan 11B															
19	6	5.0	2.8	1.1	0.4	0.4	0.7	0.5	0.6	0.4	0.4	--	0.9	0.5	7.1
Plan 11C															
17	15	6.7	2.5	1.1	0.6	0.6	0.6	0.7	0.4	0.3	0.3	--	1.1	0.7	11.6
19	6	3.8	2.2	0.8	0.3	0.3	0.5	0.4	0.5	0.3	0.4	--	0.7	0.4	5.8

Table 8

Wave Heights for Plan 12 for Test Waves from Southwest

Test Wave		Wave Height, ft, at Indicated Gage Locations												
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13
7	6	1.0	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	2.9	0.1	0.1
9	6	1.6	1.3	1.0	0.2	0.2	0.3	0.4	0.3	0.3	0.2	4.4	0.5	0.4
	11	4.6	2.0	1.1	0.5	0.2	0.5	0.5	0.5	0.5	0.3	7.9	0.7	0.7
11	6	1.2	1.4	1.0	0.3	0.3	0.2	0.2	0.3	0.3	0.4	3.7	0.3	0.5
	11	3.0	1.6	1.3	0.4	0.4	0.4	0.5	0.3	0.3	0.5	5.2	0.6	0.7
13	6	1.7	0.8	0.5	0.2	0.3	0.2	0.3	0.2	0.1	0.1	5.5	0.2	0.1
	11	4.9	2.3	0.8	0.5	0.7	0.5	0.5	0.5	0.4	0.4	10.0	0.6	0.4
15	6	2.0	1.7	1.1	0.3	0.1	0.2	0.3	0.2	0.1	0.2	4.8	0.8	0.5
	9	2.5	2.0	1.2	0.4	0.3	0.4	0.4	0.4	0.2	0.3	6.0	0.4	0.5
17	6	2.7	1.3	0.5	0.4	0.2	0.3	0.3	0.5	0.2	0.2	6.9	0.2	0.2
19	6	2.6	2.2	1.1	0.4	0.3	0.3	0.6	0.5	0.4	0.3	7.5	0.6	0.4

Table 9

Wave Heights for Plan 10B

Test Wave Period sec	Test Wave Height ft	Wave Height, ft, at Indicated Gage Locations: Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
							Northwest								
7	6	2.8	0.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.3	0.1	0.1	4.3
	9	3.0	0.9	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.0	0.1	0.1	6.3
9	6	3.0	0.5	0.3	0.3	0.1	0.2	0.2	0.1	0.2	0.1	2.2	0.1	0.2	3.5
	9	3.8	0.5	0.5	0.3	0.1	0.3	0.3	0.2	0.3	0.2	3.6	0.3	0.4	5.7
	13	4.4	0.9	0.5	0.3	0.1	0.3	0.3	0.3	0.3	0.2	4.3	0.5	0.5	9.0
11	6	1.7	0.9	0.8	0.2	0.2	0.2	0.2	0.2	0.1	0.2	2.6	0.1	0.3	4.6
	9	2.8	1.8	0.9	0.4	0.3	0.3	0.3	0.4	0.1	0.3	4.6	0.2	0.3	7.7
	15	5.2	3.1	1.8	0.6	0.5	0.6	0.6	0.6	0.4	0.7	7.4	0.6	0.9	13.7
13	6	2.1	1.7	0.7	0.3	0.5	0.6	0.5	0.5	0.2	0.3	3.5	0.2	0.2	6.9
	11	4.2	2.2	1.0	0.7	0.7	0.6	0.6	0.5	0.3	0.4	7.2	0.4	0.2	15.8
	17	10.0	4.0	1.5	0.6	0.7	0.5	0.5	0.5	0.4	0.4	8.2	0.8	0.4	14.2
15	6	2.0	2.3	1.1	0.3	0.1	0.2	0.2	0.2	0.1	0.1	4.4	0.7	0.6	6.2
	11	3.6	3.3	1.6	0.6	0.5	0.4	0.4	0.4	0.3	0.6	7.7	0.9	0.8	10.9
	17	7.8	4.7	2.6	1.0	0.8	0.6	0.6	0.9	0.5	0.6	14.8	1.1	0.9	14.8
17	6	2.9	2.5	1.0	0.7	0.6	0.4	0.4	0.3	0.3	0.2	2.9	0.6	0.5	5.2
	11	6.2	4.0	1.7	1.4	1.0	0.9	0.7	0.6	0.5	0.3	7.0	1.5	0.5	11.8
	15	11.5	4.2	1.7	2.2	1.0	1.1	1.0	0.9	0.5	0.4	8.0	1.7	1.1	14.6
19	6	4.1	2.3	0.9	0.4	0.3	0.5	0.5	1.0	0.5	0.3	3.1	1.2	0.5	5.9

(Continued)

Table 9 (Continued)

Test Wave		Wave Height, ft, at Indicated Gage Locations													
Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
							West								
7	6	0.9	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.0	0.1	0.1	4.0
	9	1.3	0.6	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	4.3	0.1	0.1	5.4
9	6	1.7	0.6	0.4	0.1	0.1	0.2	0.1	0.1	0.2	0.1	3.4	0.2	0.3	3.0
	11	2.3	0.9	0.6	0.2	0.1	0.3	0.1	0.2	0.3	0.2	5.5	0.4	0.3	5.5
11	6	2.2	0.7	0.5	0.2	0.1	0.2	0.1	0.3	0.1	0.2	3.0	0.2	0.2	4.5
	13	5.1	1.7	1.2	0.4	0.2	0.4	0.3	0.5	0.3	0.4	8.0	0.3	0.5	10.5
13	6	1.5	0.6	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.1	4.7	0.1	0.2	5.3
	15	5.6	2.7	1.5	0.6	0.4	0.4	0.6	0.5	0.3	0.4	9.9	0.8	0.6	13.4
15	6	2.1	0.6	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	4.2	0.1	0.1	4.7
	13	5.1	1.9	0.6	0.4	0.3	0.3	0.2	0.2	0.2	0.3	8.2	0.3	0.3	10.4
17	6	2.0	0.8	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	4.6	0.1	0.1	4.0
	13	7.5	2.2	0.8	0.6	0.3	0.4	0.3	0.4	0.3	0.3	9.6	0.5	0.4	9.3
19	6	2.1	1.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	4.9	0.6	0.5	4.5

(Continued)

(Sheet 2 of 3)

Table 9 (Concluded)

Test Wave Period sec	Test Wave Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14
		Southwest													
7	6	0.9	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	2.7	0.1	0.1	1.7
9	6	1.4	1.2	1.0	0.2	0.2	0.2	0.3	0.3	0.2	0.2	3.8	0.6	0.4	2.2
	11	3.1	1.0	1.0	0.4	0.2	0.4	0.3	0.4	0.4	0.3	5.2	0.6	0.5	4.7
11	6	1.0	1.0	0.9	0.4	0.3	0.3	0.3	0.2	0.3	0.3	2.6	0.2	0.4	3.3
	11	3.6	1.3	1.4	0.4	0.4	0.5	0.5	0.4	0.4	0.5	10.0	0.6	0.8	5.9
13	6	1.5	0.7	0.4	0.1	0.4	0.4	0.3	0.3	0.2	0.2	4.0	0.1	0.2	3.6
	11	4.4	2.1	1.0	0.5	0.5	0.4	0.5	0.4	0.3	0.3	14.9	0.5	0.4	6.9
15	6	1.8	0.8	0.5	0.3	0.2	0.2	0.2	0.2	0.1	0.2	4.9	0.1	0.1	4.4
	9	2.7	1.9	1.0	0.6	0.3	0.3	0.4	0.2	0.3	0.2	9.4	0.3	0.2	5.0
17	6	2.3	0.6	0.4	0.4	0.2	0.2	0.2	0.2	0.1	0.1	6.0	0.3	0.3	2.7
19	6	2.3	1.2	0.8	0.3	0.7	0.3	0.3	0.6	0.4	0.3	5.7	0.5	0.3	2.3

(Sheet 3 of 3)

Table 10

Wave Heights in Surfing Areas for Plan 10B

Test Wave		Wave Height, ft, at Indicated Direction and Gage Locations					
		Northwest		West		Southwest	
Period sec	Height ft	Gage 15	Gage 16	Gage 15	Gage 16	Gage 15	Gage 16
7	6	9.0	2.1	7.1	2.4	1.3	6.7
	9	11.2	2.4	9.1	6.1	--	--
9	3	4.1	1.0	3.0	1.1	0.8	2.3
	6	9.7	1.9	7.7	3.2	2.2	7.0
	9	12.3	2.7	--	--	--	--
	11	--	--	12.1	8.9	4.9	9.9
	13	8.0	4.7	--	--	--	--
11	3	7.8	0.9	3.0	1.2	1.0	1.5
	6	14.2	1.3	6.7	2.3	2.3	4.2
	9	11.5	2.9	--	--	--	--
	11	--	--	--	--	5.0	10.7
	13	--	--	8.8	9.0	--	--
	15	13.1	9.1	--	--	--	--
13	3	9.4	1.2	4.0	1.3	1.4	1.7
	6	13.7	2.5	9.8	3.6	2.9	11.7
	11	11.7	10.0	--	--	9.0	10.6
	15	--	--	9.9	10.1	--	--
	17	11.6	9.3	--	--	--	--
15	6	12.1	2.7	9.8	7.3	3.7	12.0
	9	--	--	--	--	6.5	12.4
	11	11.5	6.9	--	--	--	--
	13	--	--	10.4	8.6	--	--
	17	13.1	11.7	--	--	--	--
17	6	14.0	8.7	10.1	8.9	5.0	11.8
	11	13.1	9.2	--	--	--	--
	13	--	--	10.2	8.6	--	--
	15	16.2	9.3	--	--	--	--
19	6	11.6	5.8	11.3	9.5	5.0	10.1

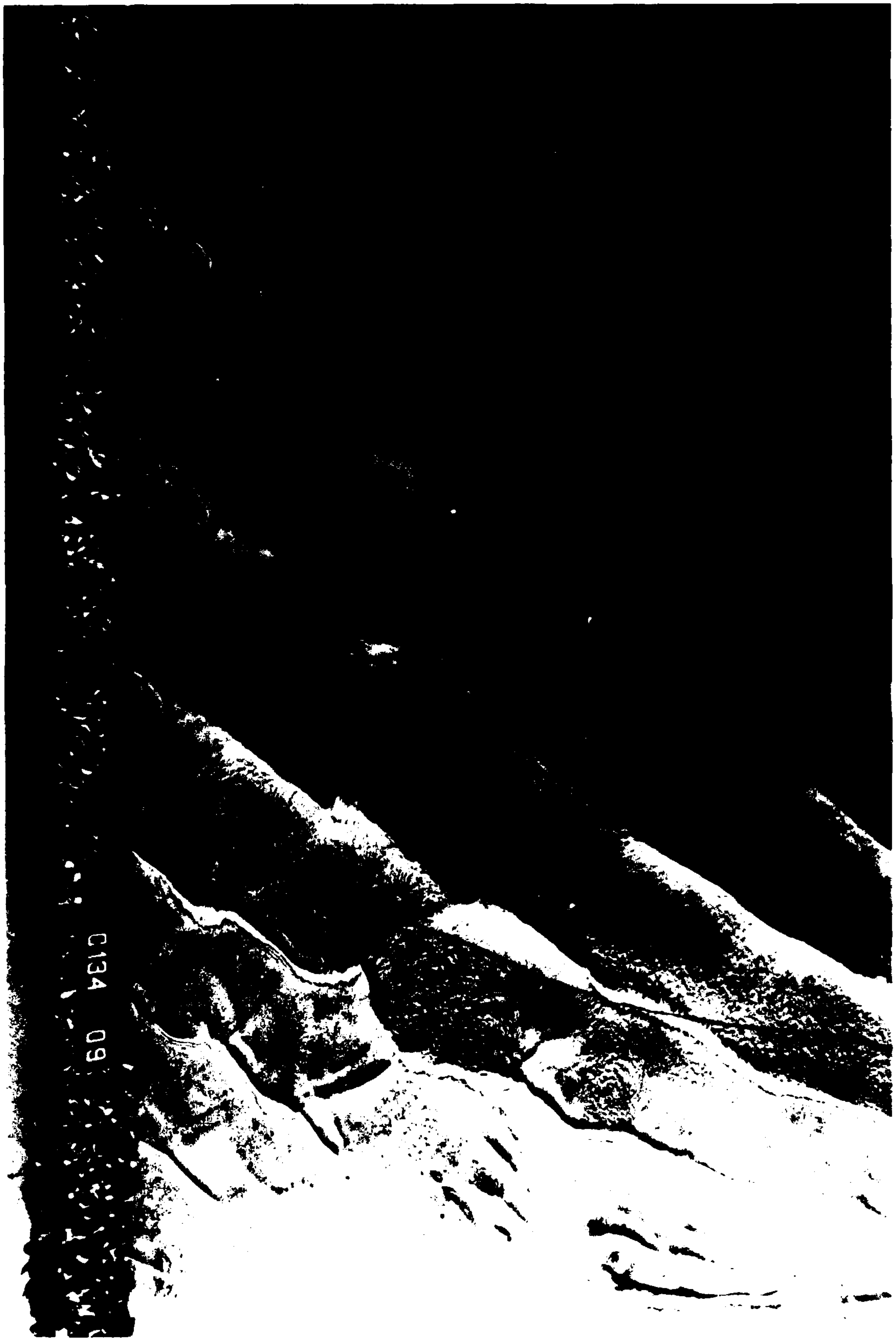


Photo 1. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 9-sec, 3-ft waves from northwest

Photo 2. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 11-sec, 3-ft waves from northwest

Photo 3. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 13-sec, 3-ft waves from northwest

Photo 4. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 9-sec, 3-ft waves from west

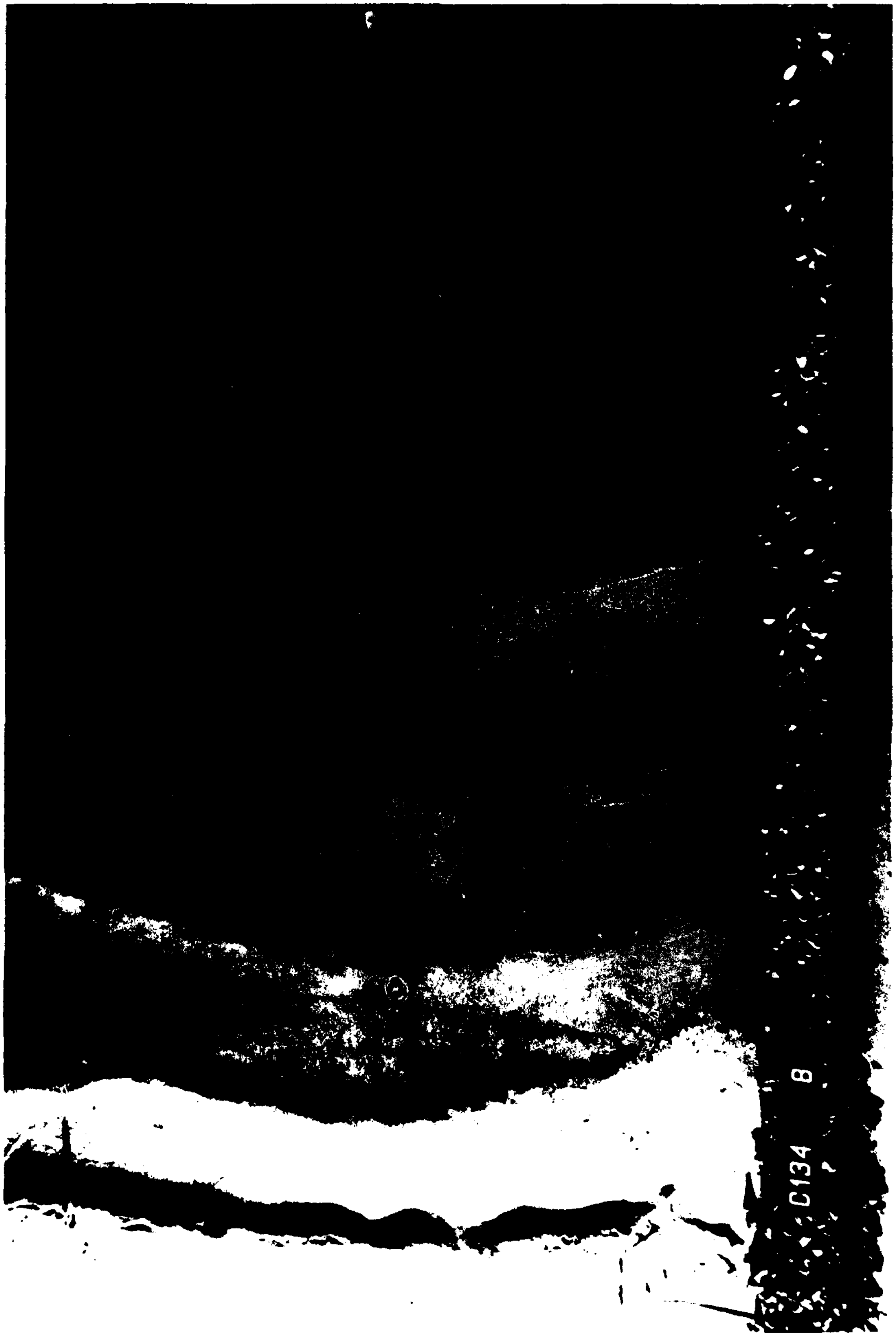


Photo 5. Typical wave patterns adjacent to the middle jetty at Ocean Beach for existing conditions; 9-sec, 3-ft waves from west

Photo 6. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 9-sec, 6-ft waves from west

Photo 7. Typical wave patterns adjacent to the middle jetty at Ocean Beach for existing conditions; 9-sec, 6-ft waves from west

Photo 8. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 11-sec, 3-ft waves from west

Photo 9. Typical wave patterns adjacent to the north jetty at Mission Beach for existing conditions; 13-sec, 3-ft waves from west

Photo 10. Typical wave patterns adjacent to the middle jetty at Ocean Beach for existing conditions; 11-sec, 3-ft waves from southwest

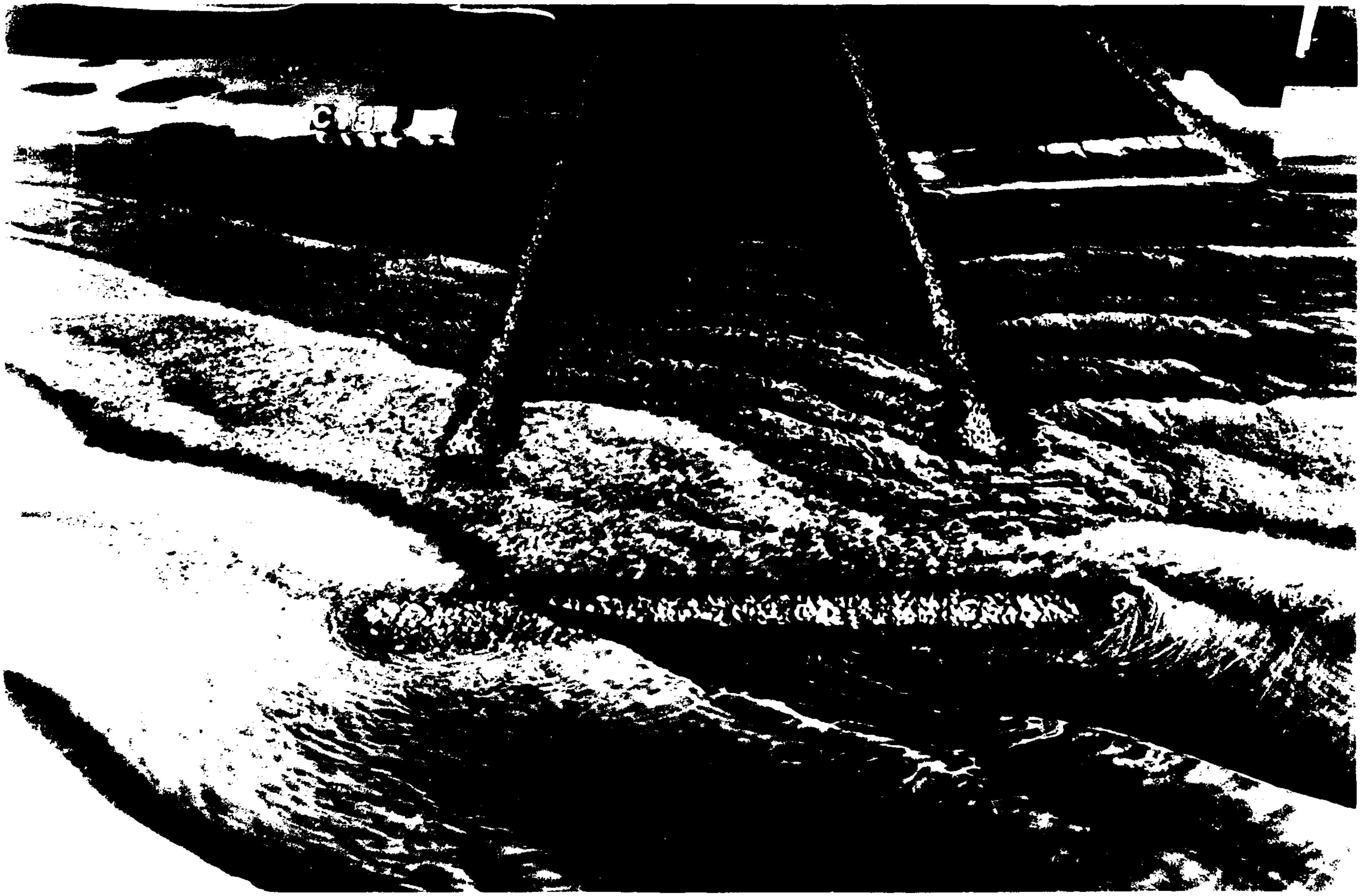


Photo 11. Typical wave patterns for Plan 10; 17-sec, 15-ft waves from northwest

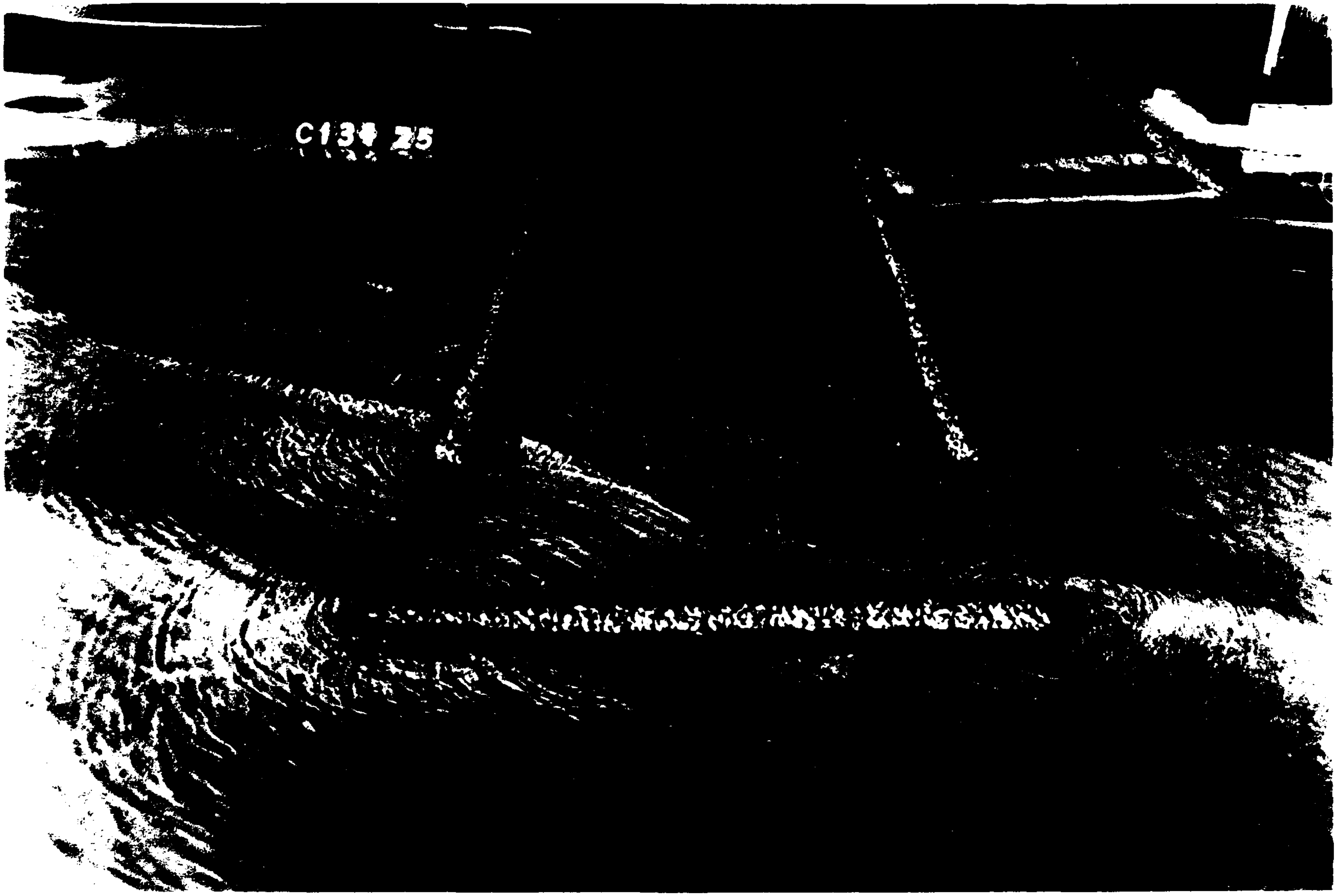


Photo 12. Typical wave patterns for Plan 10; 19-sec, 6-ft waves from northwest

Photo 13. Typical wave patterns for Plan 10A; 17-sec, 15-ft waves from northwest

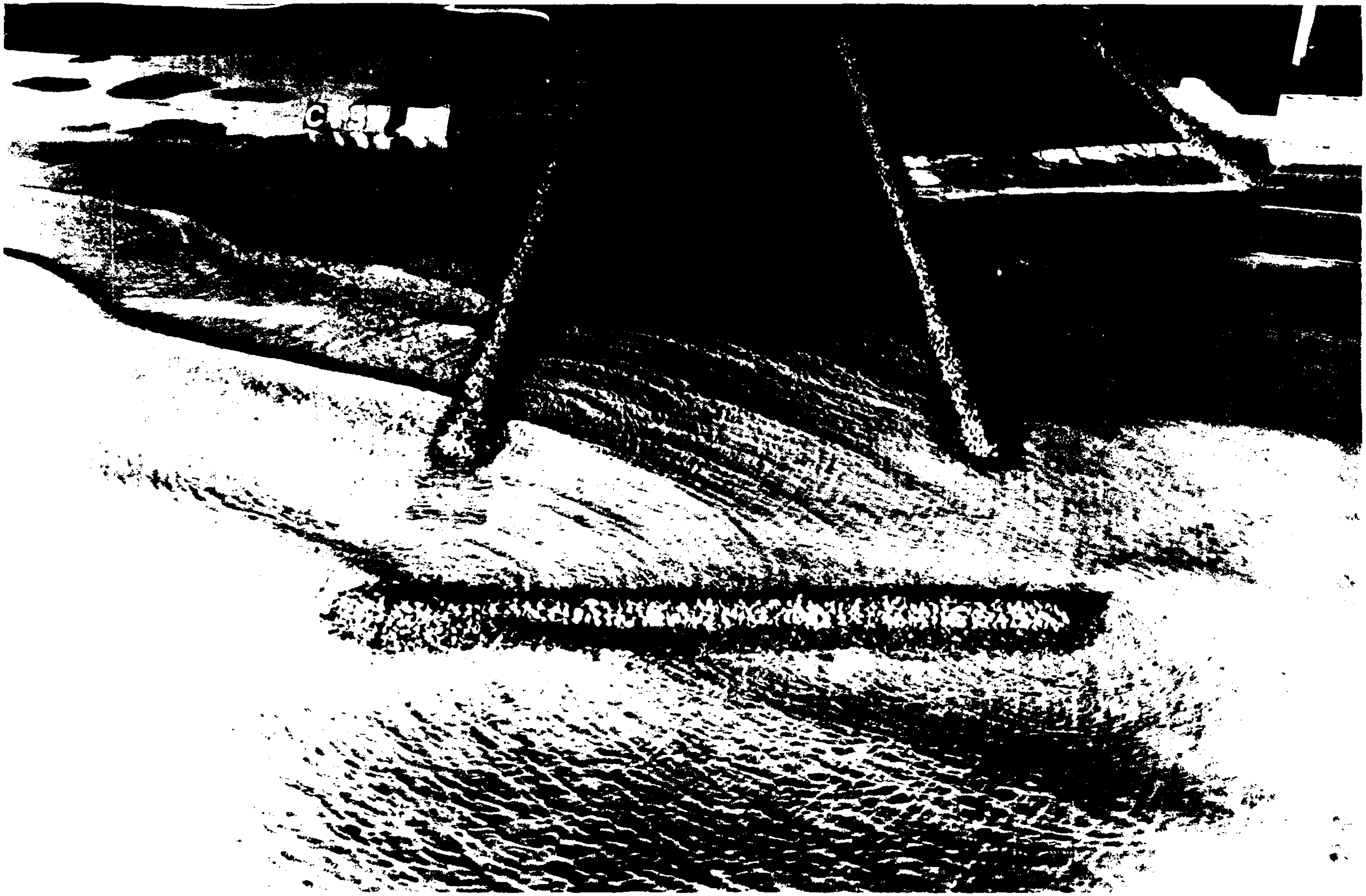


Photo 14. Typical wave patterns fro Plan 10A; 19-sec, 6-ft waves from northwest

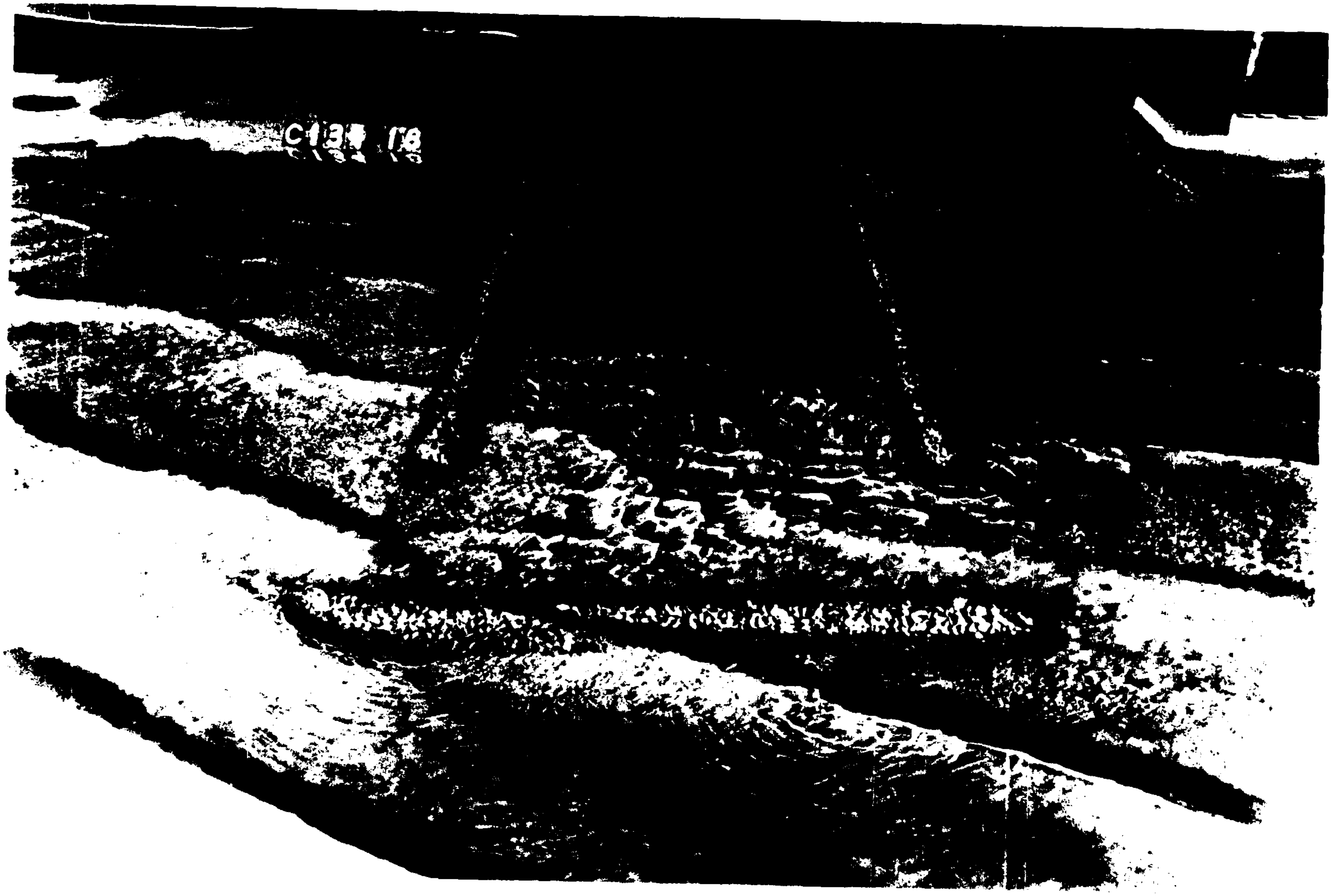


Photo 15. Typical wave patterns for Plan 10B; 17-sec, 15-ft waves from northwest

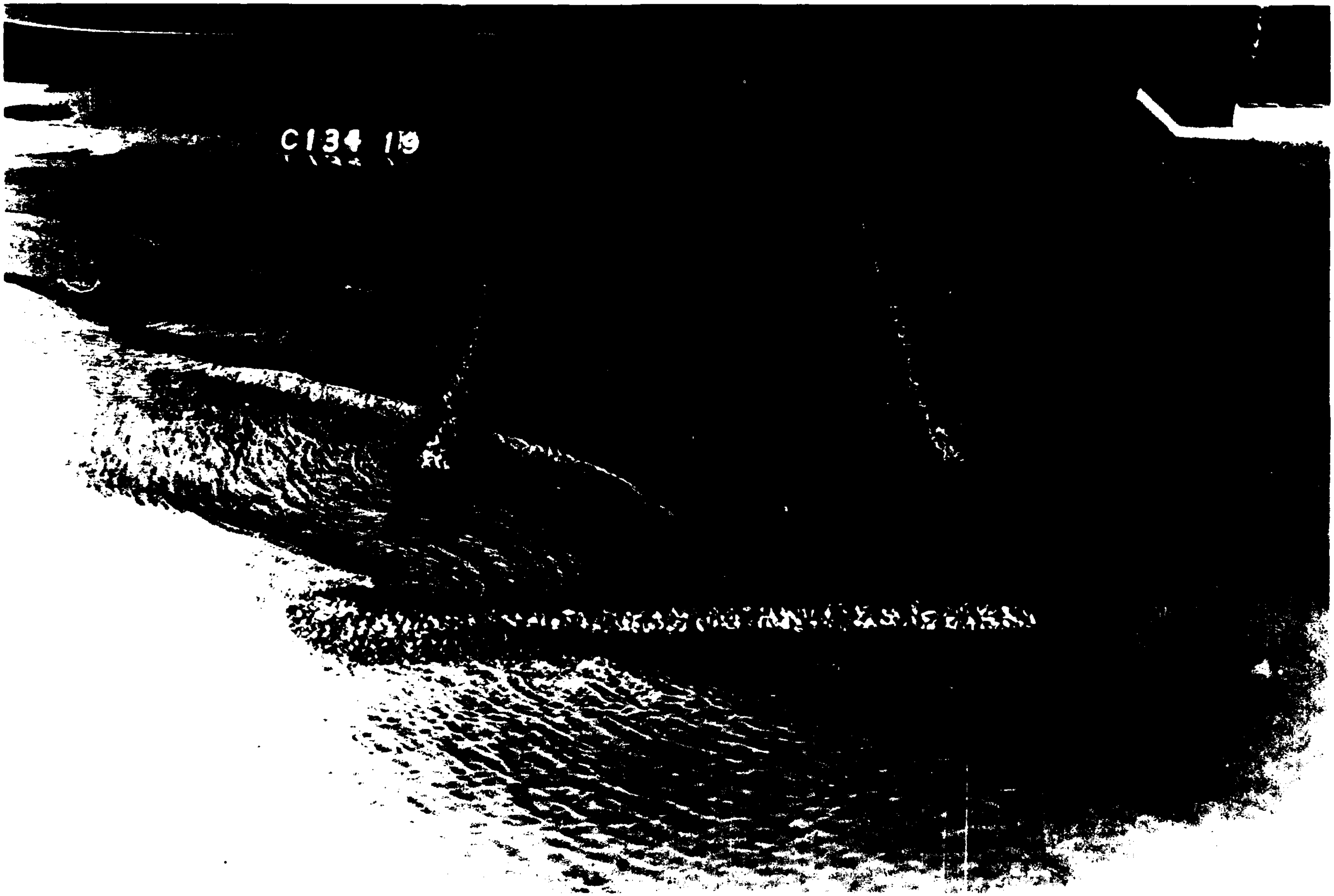


Photo 16. Typical wave patterns for Plan 10B; 19-sec, 6-ft waves from northwest

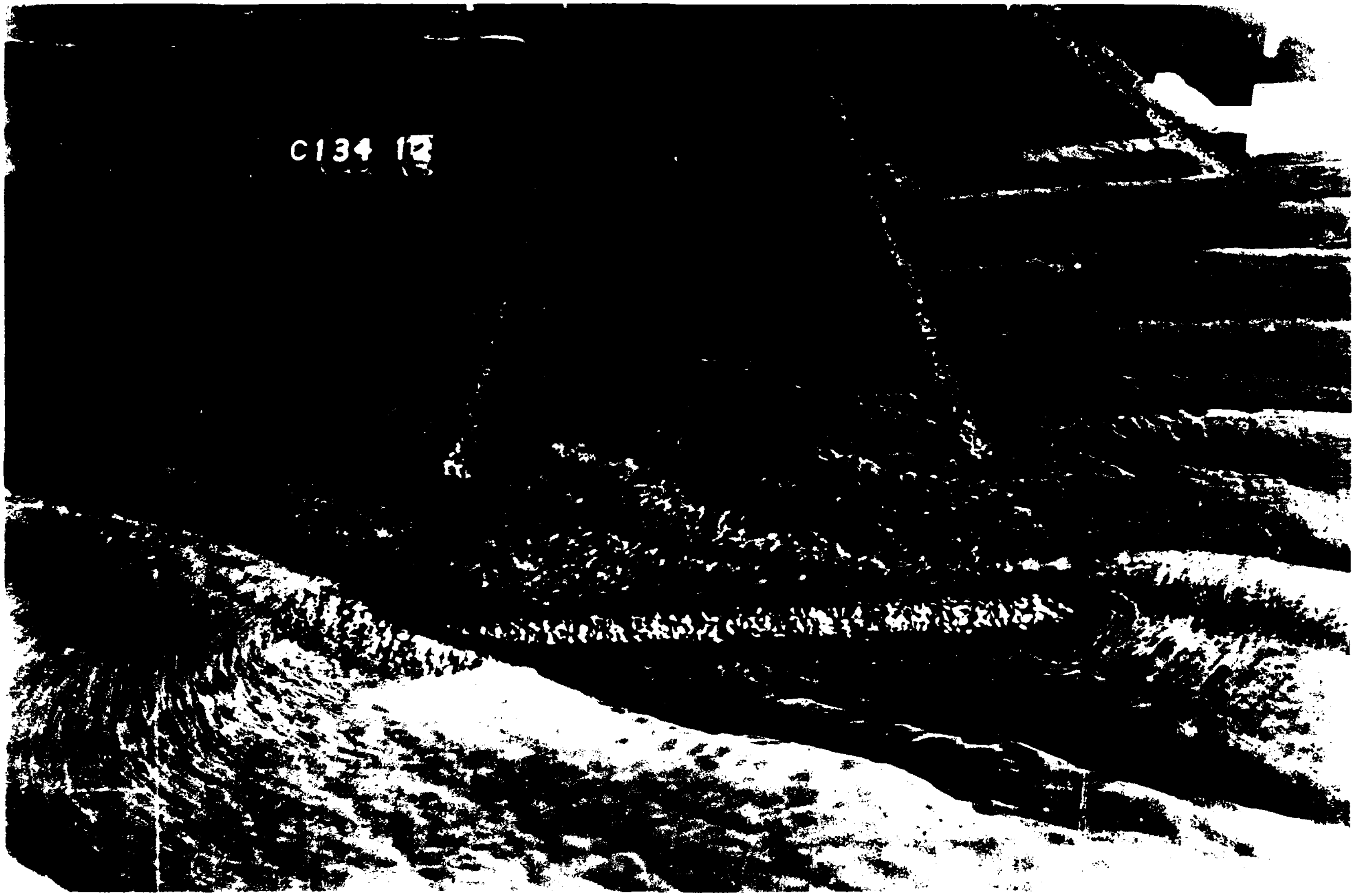


Photo 17. Typical wave patterns for Plan 10C; 17-sec, 15-ft waves from northwest

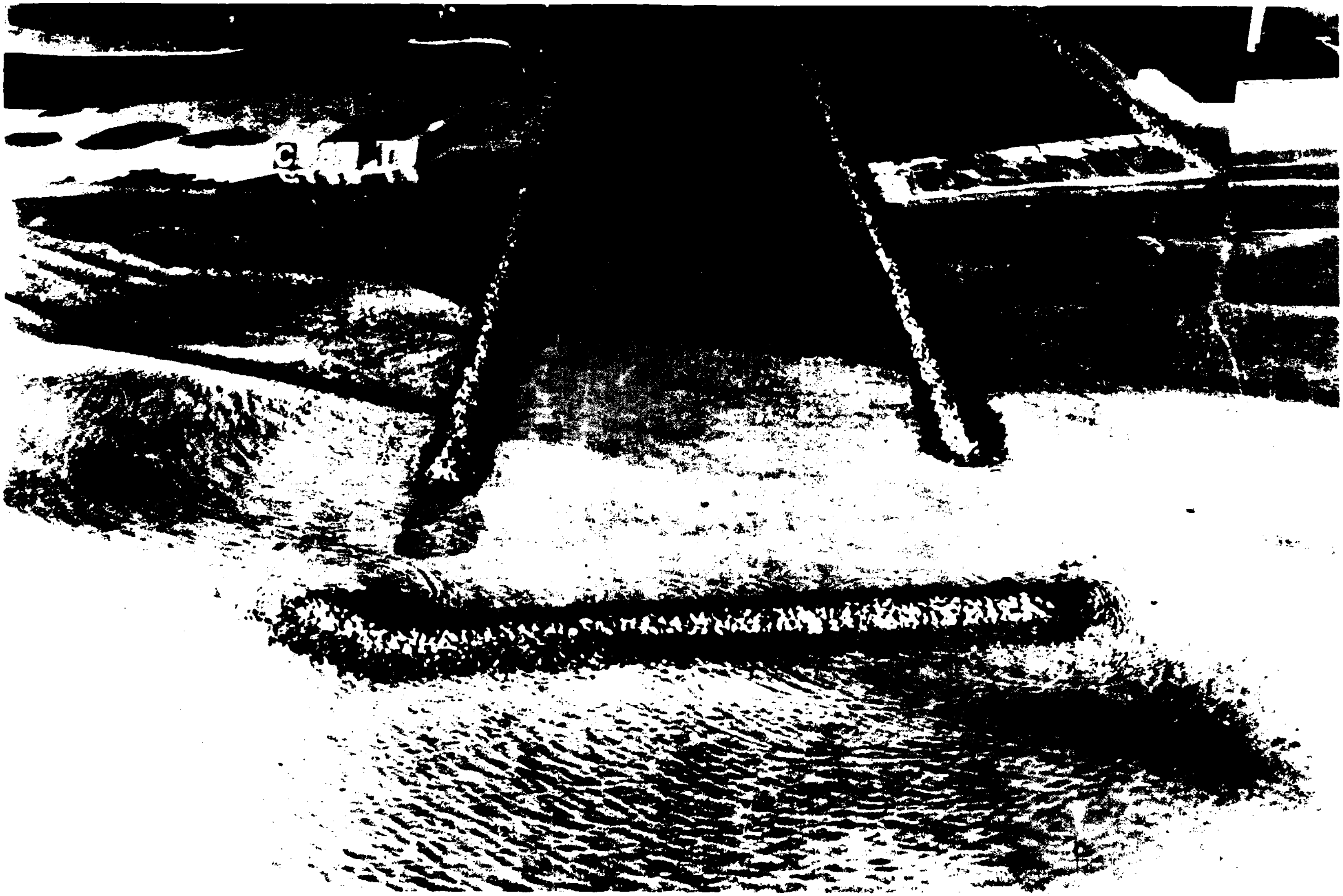


Photo 18. Typical wave patterns for Plan 10C; 19-sec, 6-ft waves from northwest

Photo 19. Typical wave patterns for Plan 10D; 17-sec, 15-ft waves from northwest

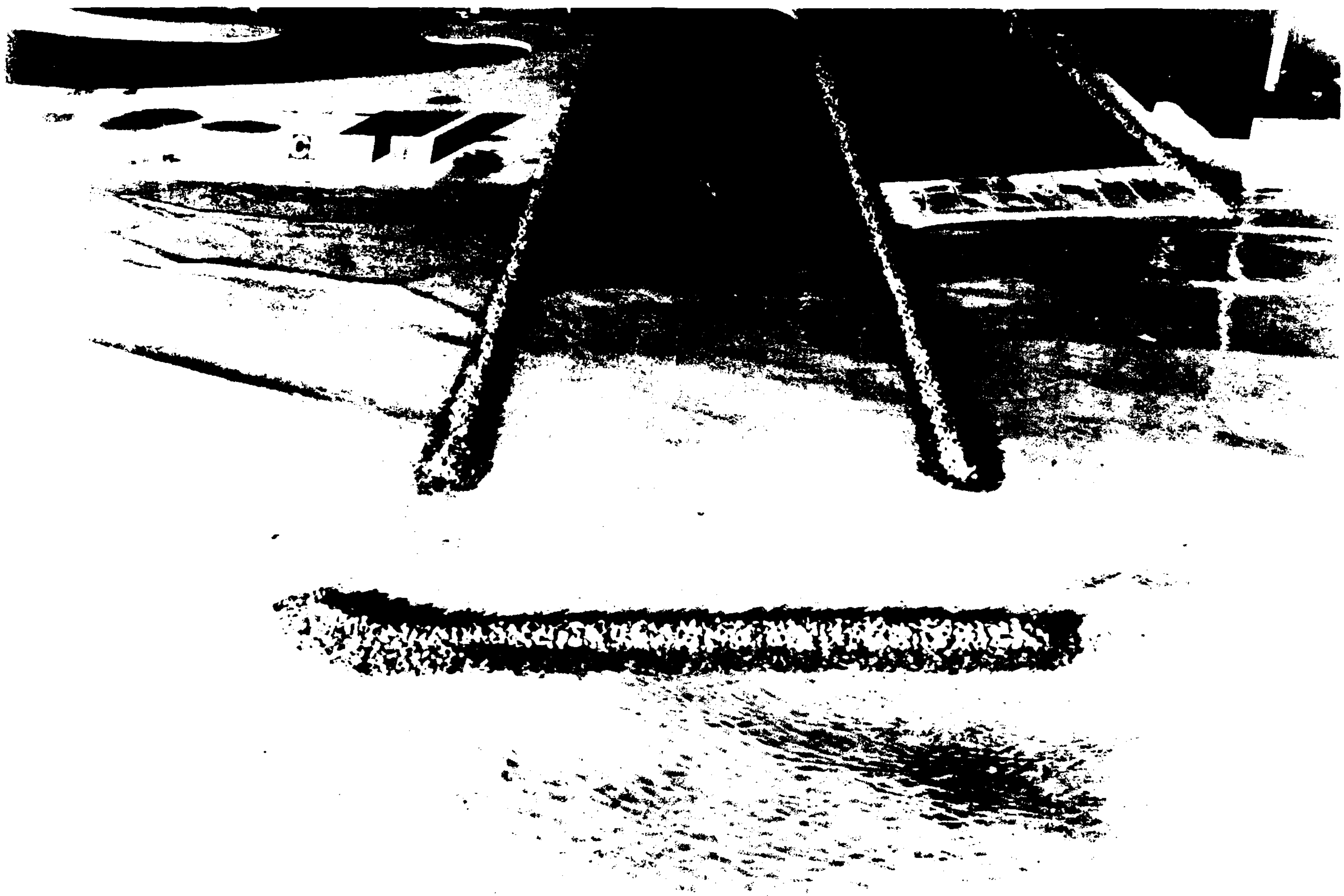


Photo 20. Typical wave patterns for Plan 10D; 19-sec, 6-ft waves from northwest

Photo 21. Typical wave patterns for Plan 10C; 19-sec, 6-ft waves from southwest

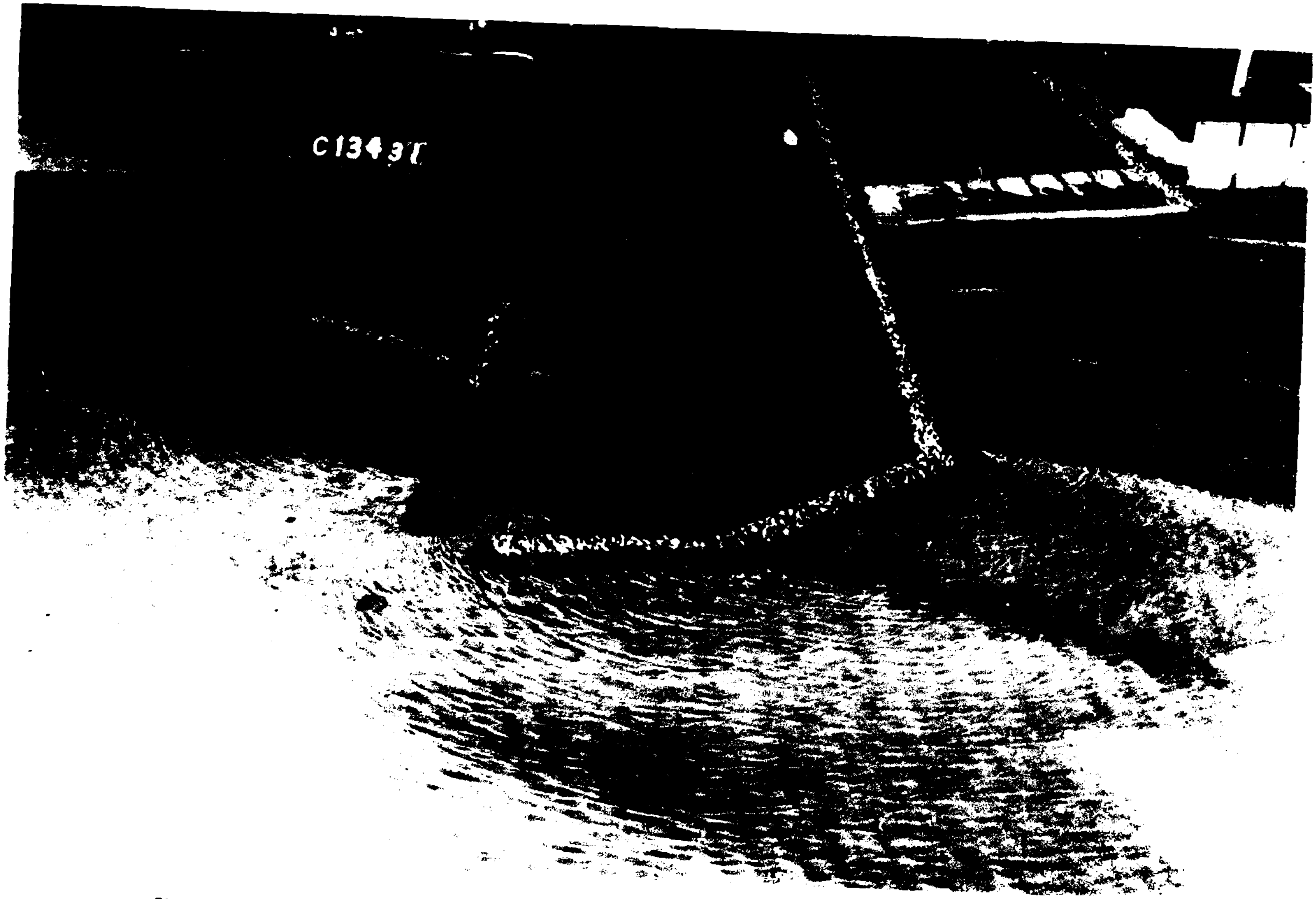


Photo 22. Typical wave patterns for Plan 11, 19-sec, 6-ft waves from northwest

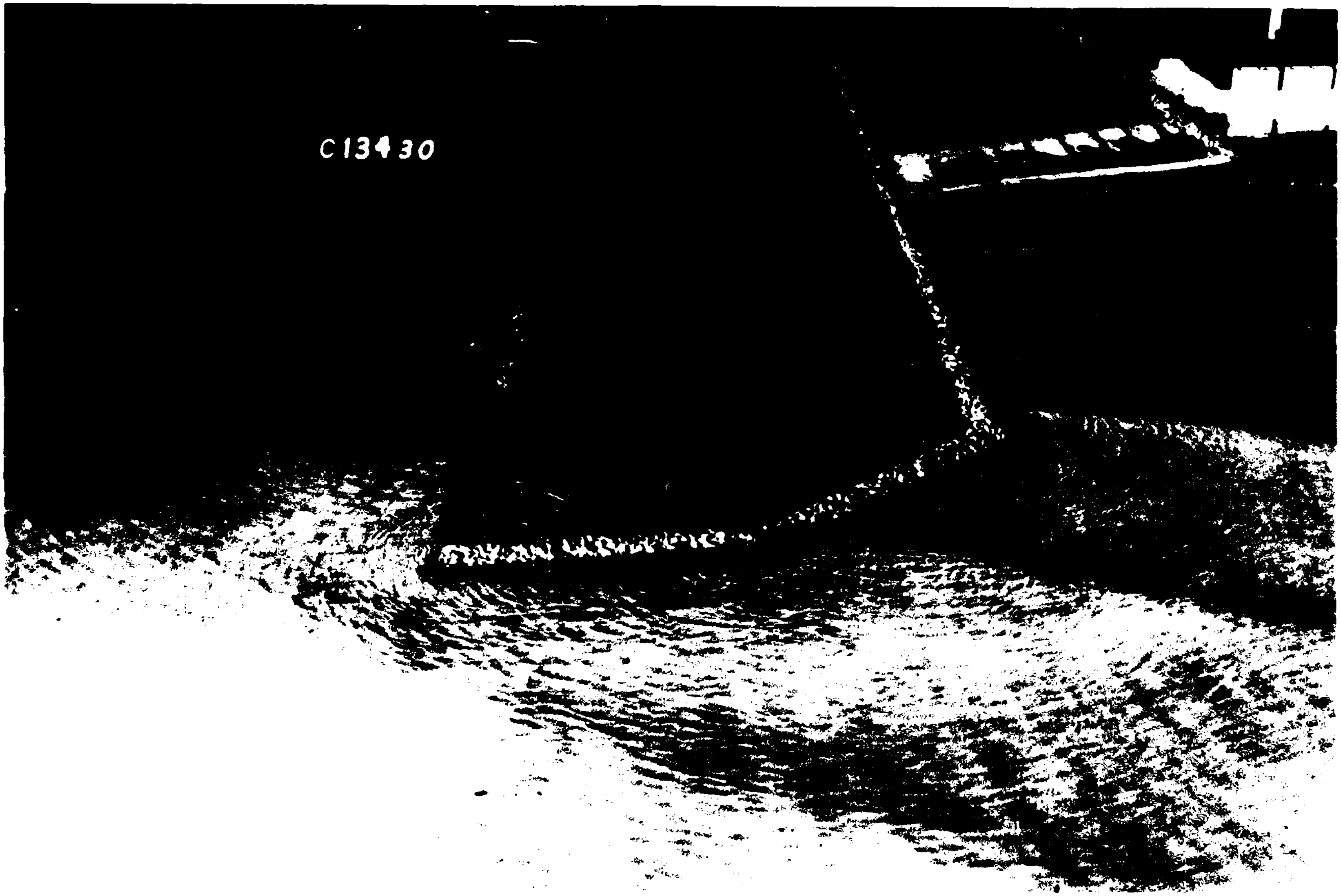


Photo 23. Typical wave patterns for Plan 11A; 19-sec, 6-ft waves from northwest

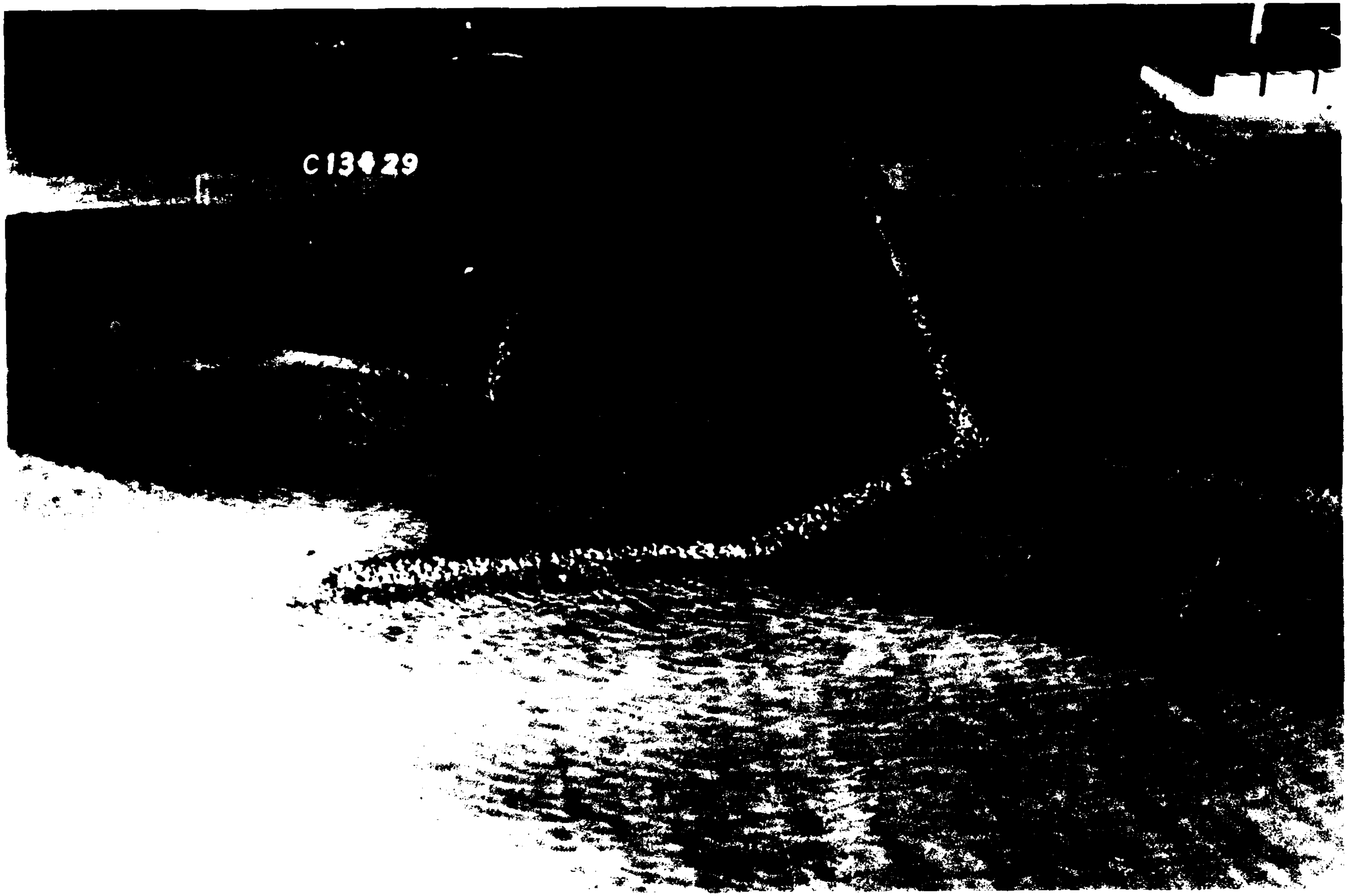


Photo 24. Typical wave patterns for Plan 11B; 19-sec, 6-ft waves from northwest

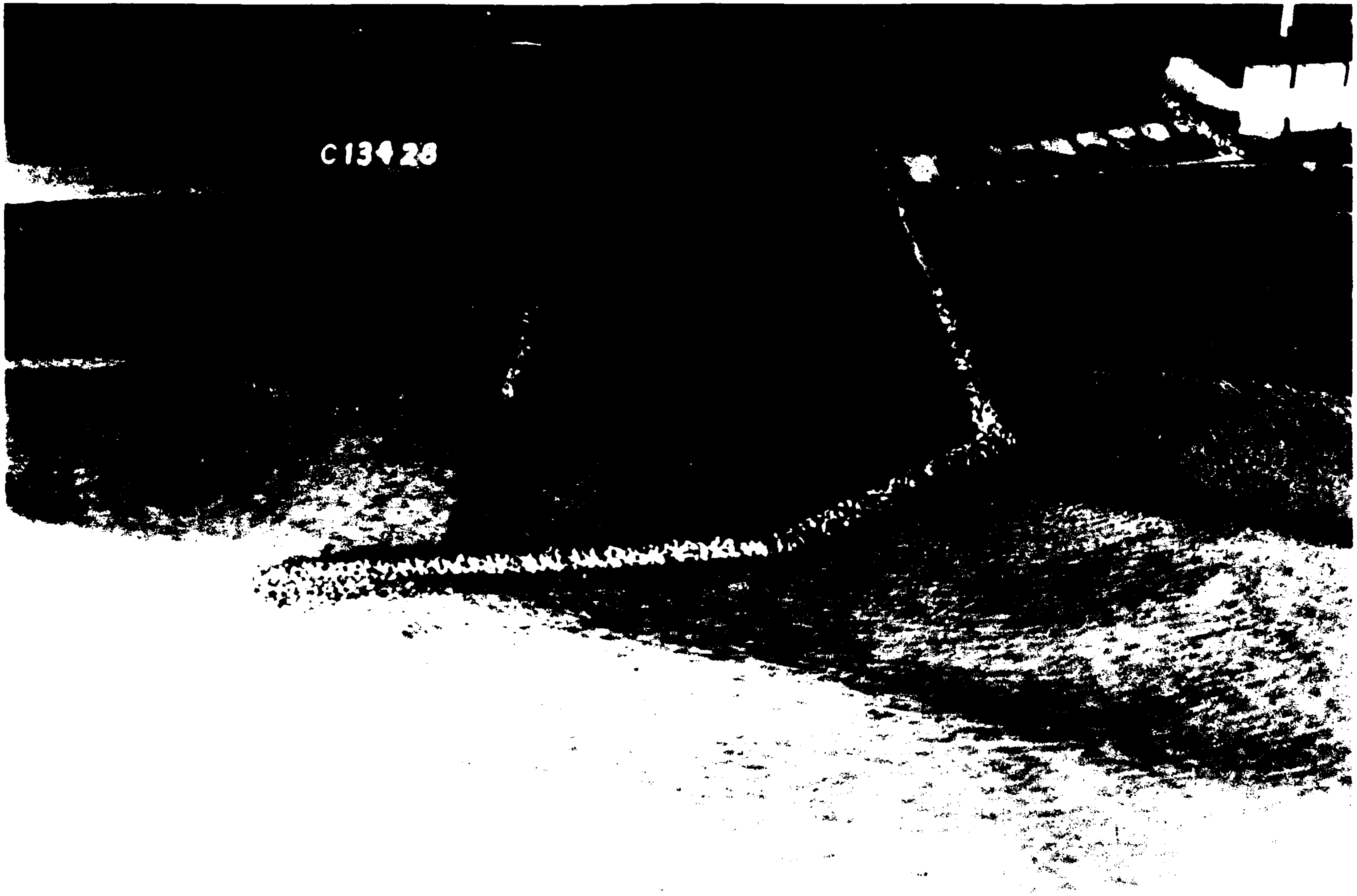


Photo 25. Typical wave patterns for Plan 11C; 19-sec, 6-ft waves from northwest

Photo 26. Typical wave patterns for Plan 11C; 17-sec, 15-ft waves from northwest

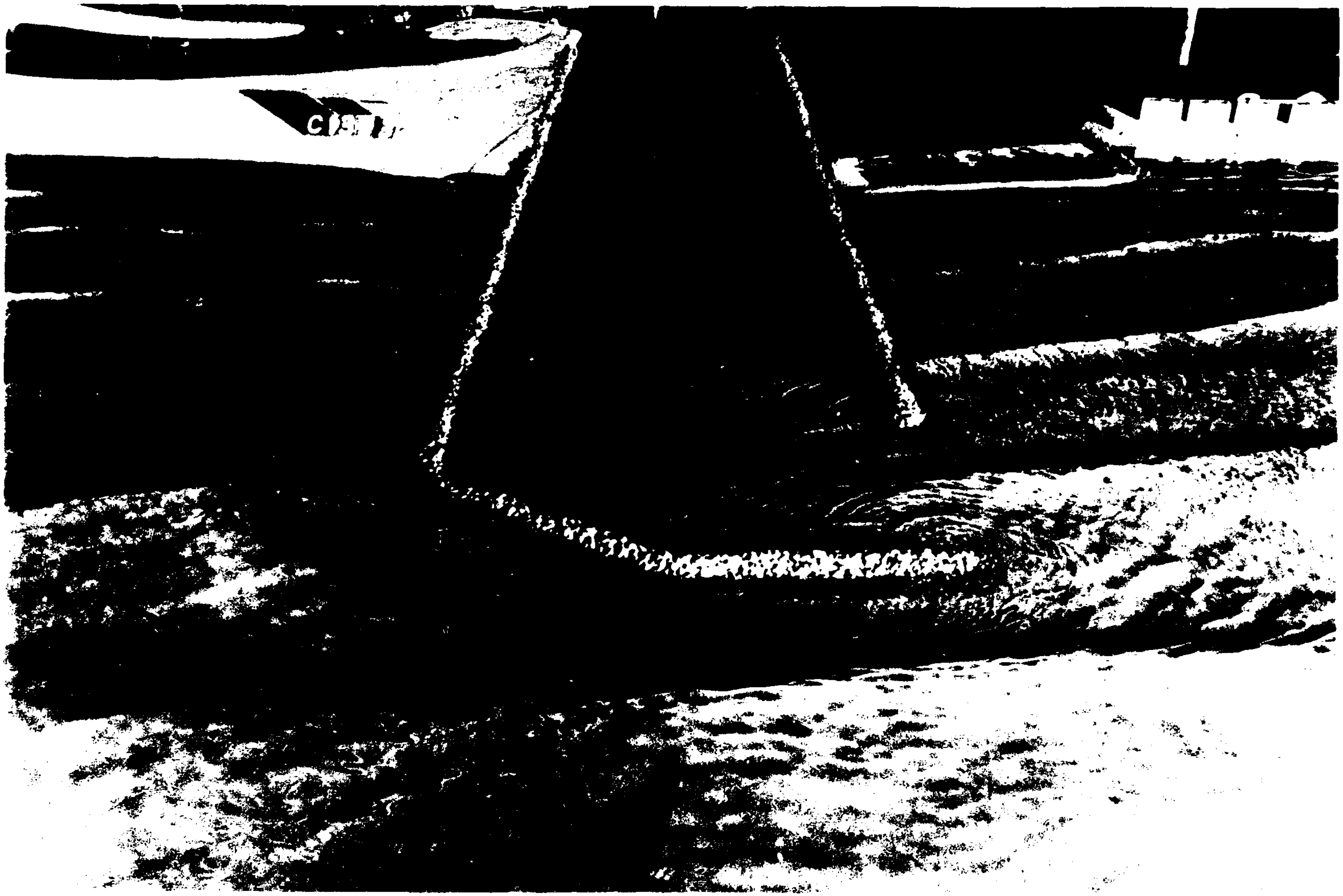


Photo 27. Typical wave patterns for Plan 12; 19-sec, 6-ft waves from southwest

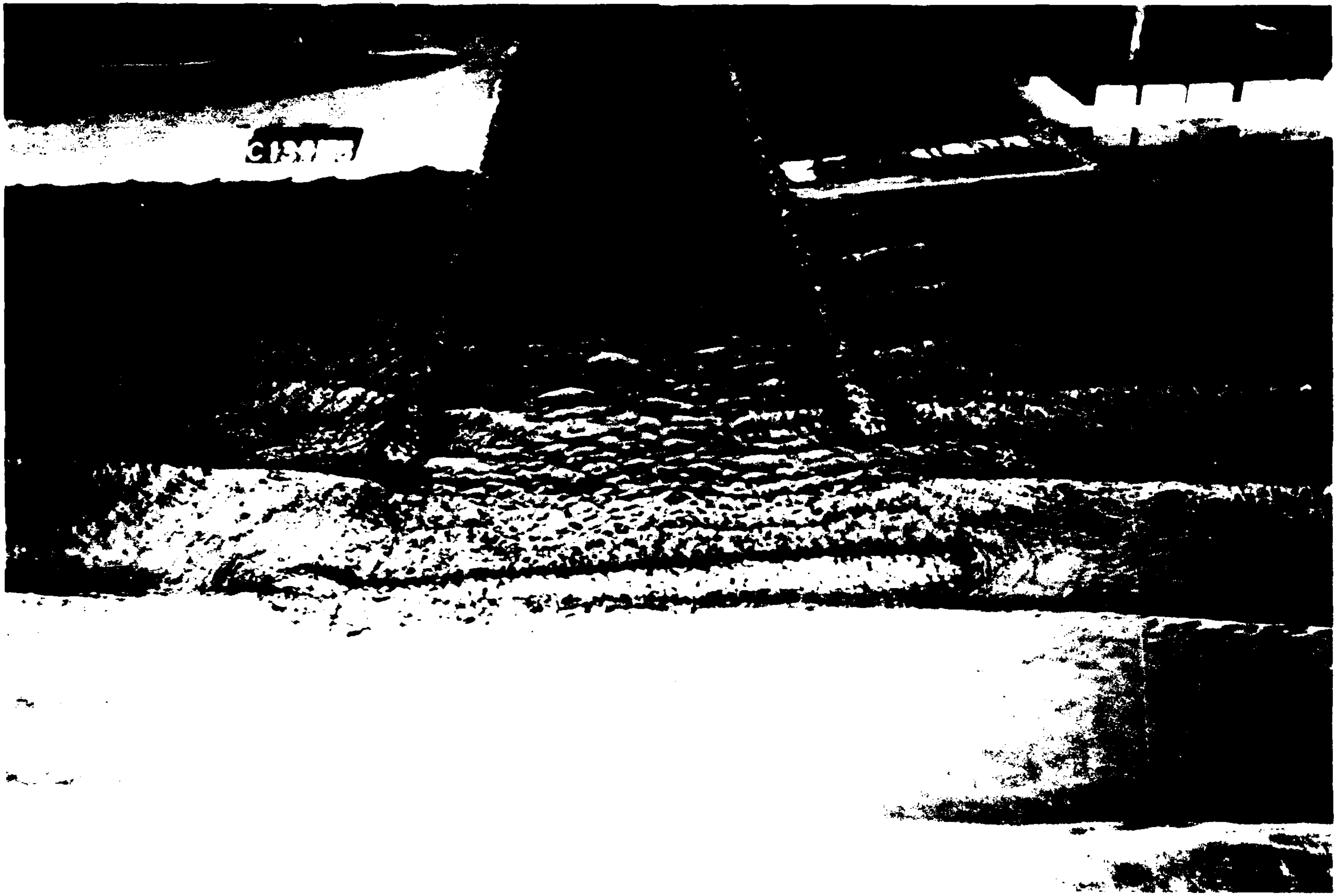


Photo 28. Typical wave patterns for Plan 10B; 13-sec, 15-ft waves from west

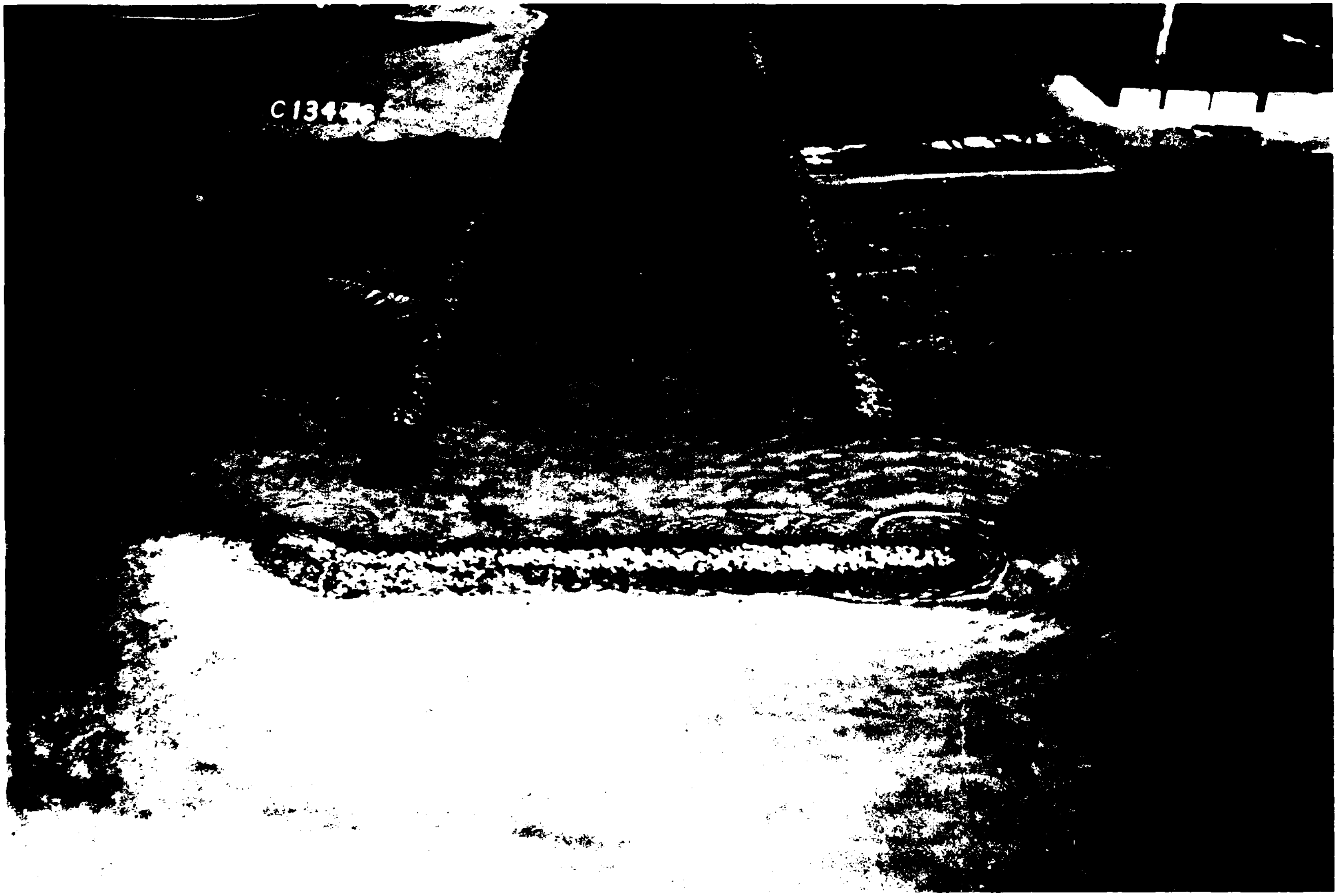


Photo 29. Typical wave patterns for Plan 10B; 19-sec, 6-ft waves from west

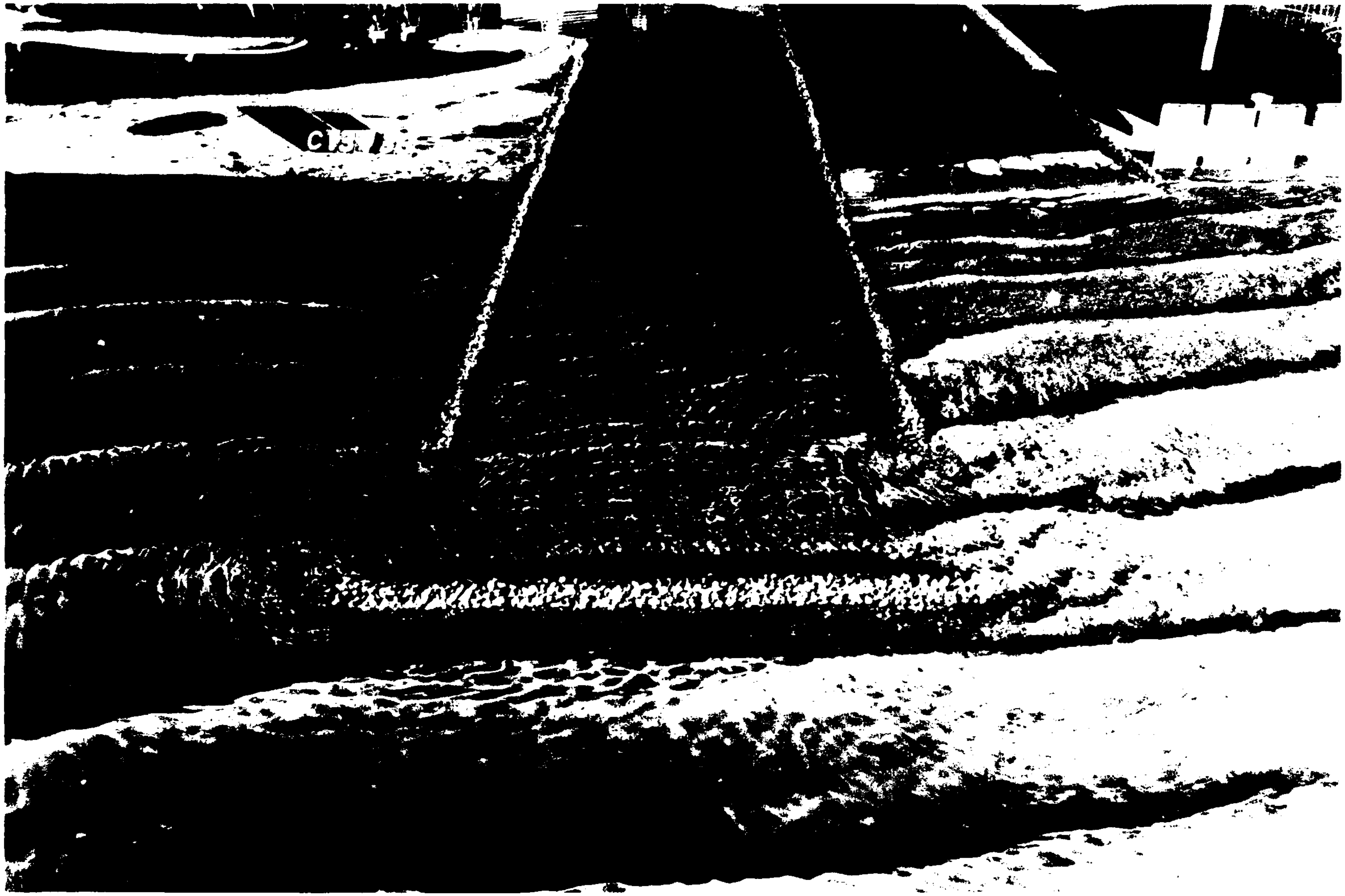


Photo 30. Typical wave patterns for Plan 10B; 13-sec, 11-ft waves from southwest

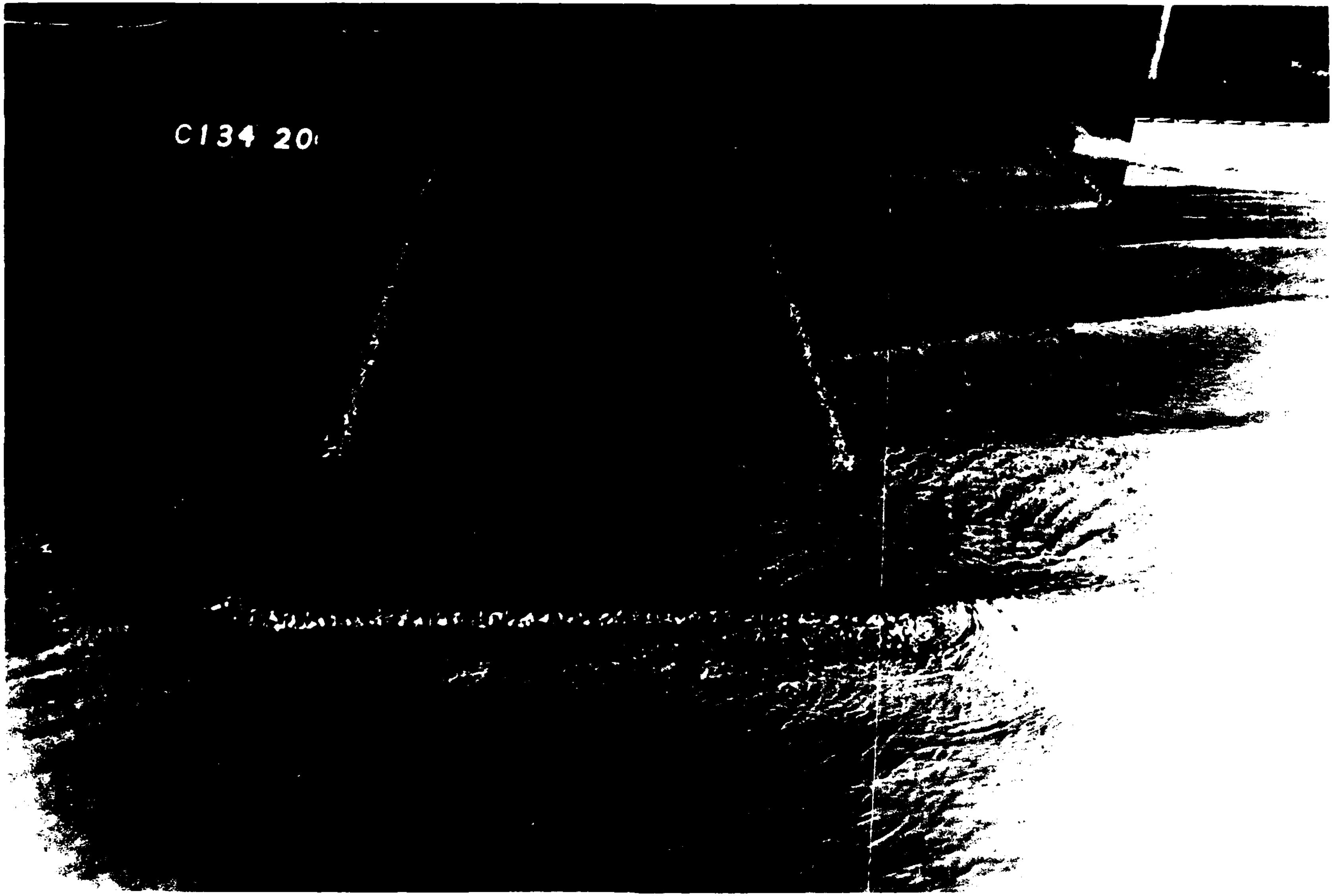


Photo 31. Typical wave patterns for Plan 10B; 19-sec, 6-ft waves from southwest

Photo 32. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 9-sec, 3-ft waves from northwest

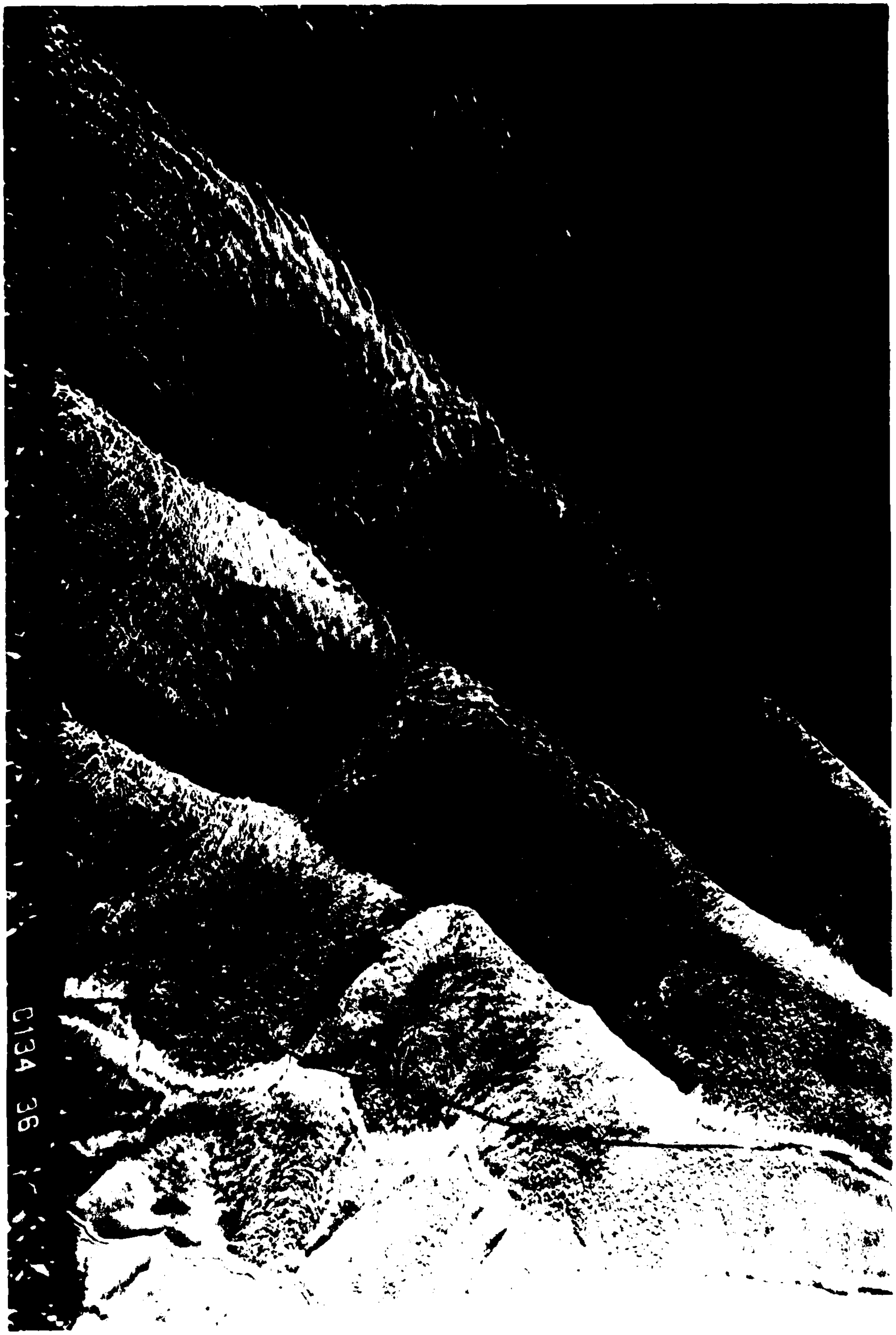


Photo 33. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 11-sec, 3-ft waves from northwest

Photo 34. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 13-sec, 3-ft waves from northwest

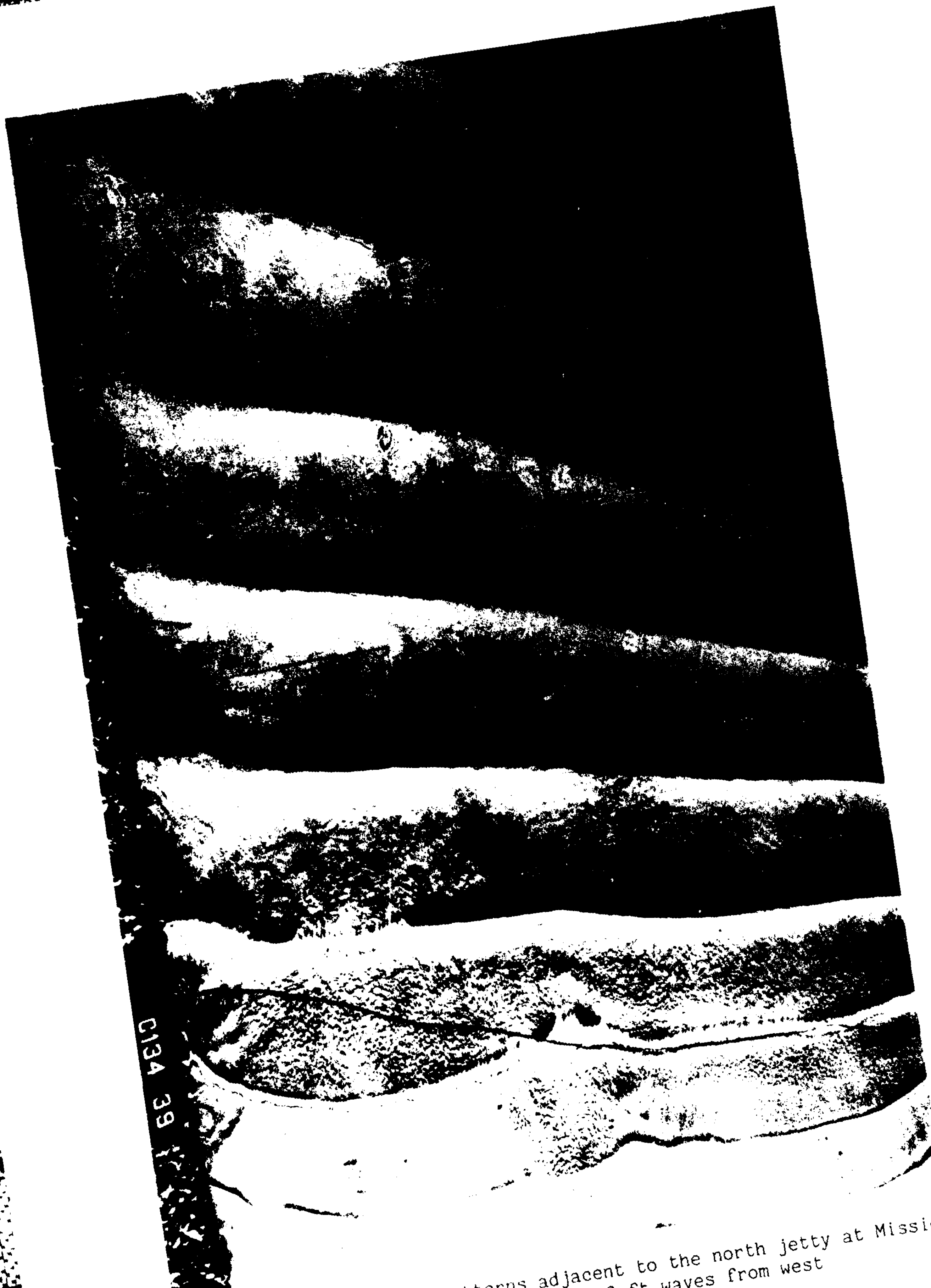


Photo 35. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 9-sec, 3-ft waves from west

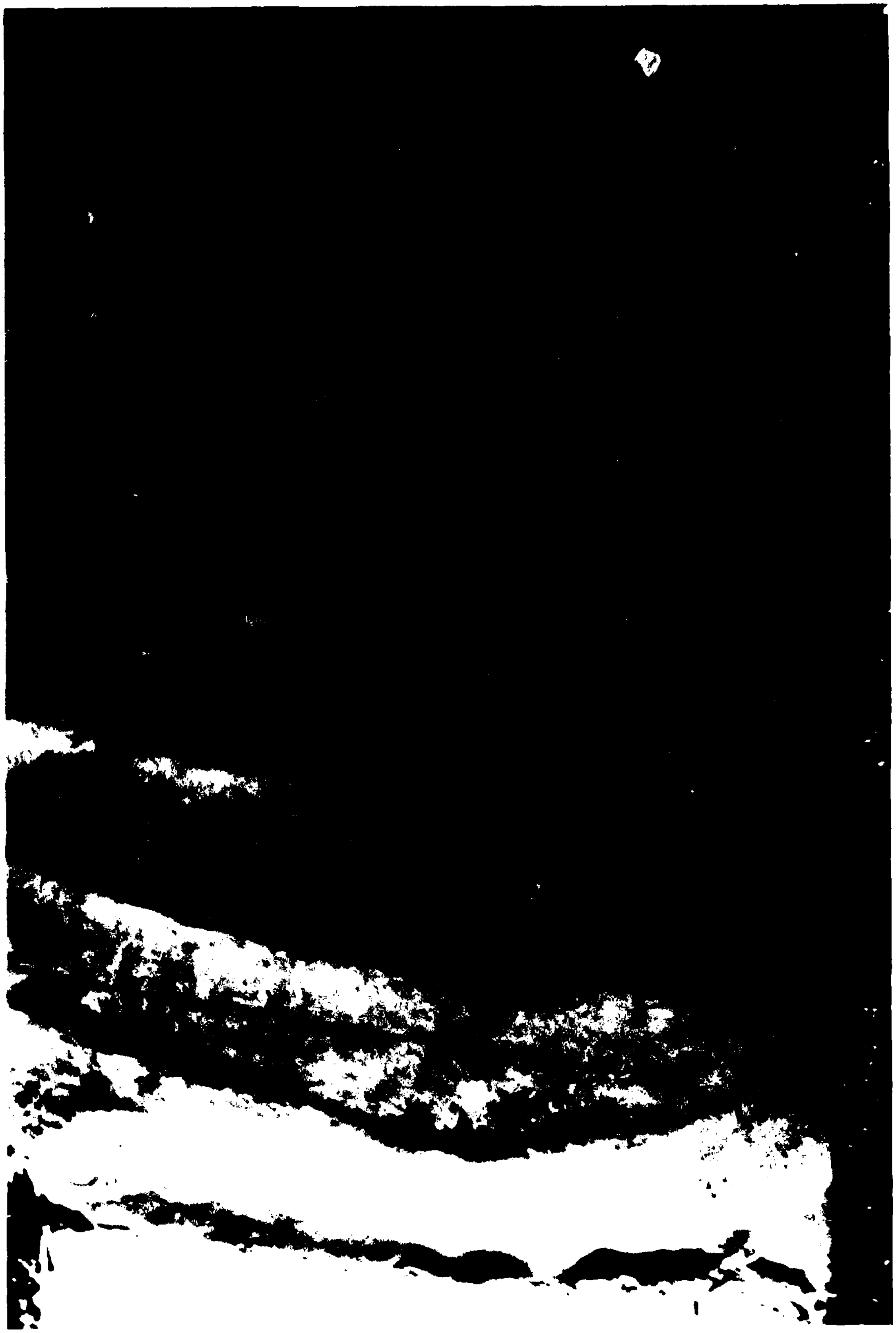


Photo 36. Typical wave patterns adjacent to the middle jetty at Ocean Beach for Plan 10B; 9-sec, 3-ft waves from west

Photo 37. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 9-sec, 6-ft waves from west

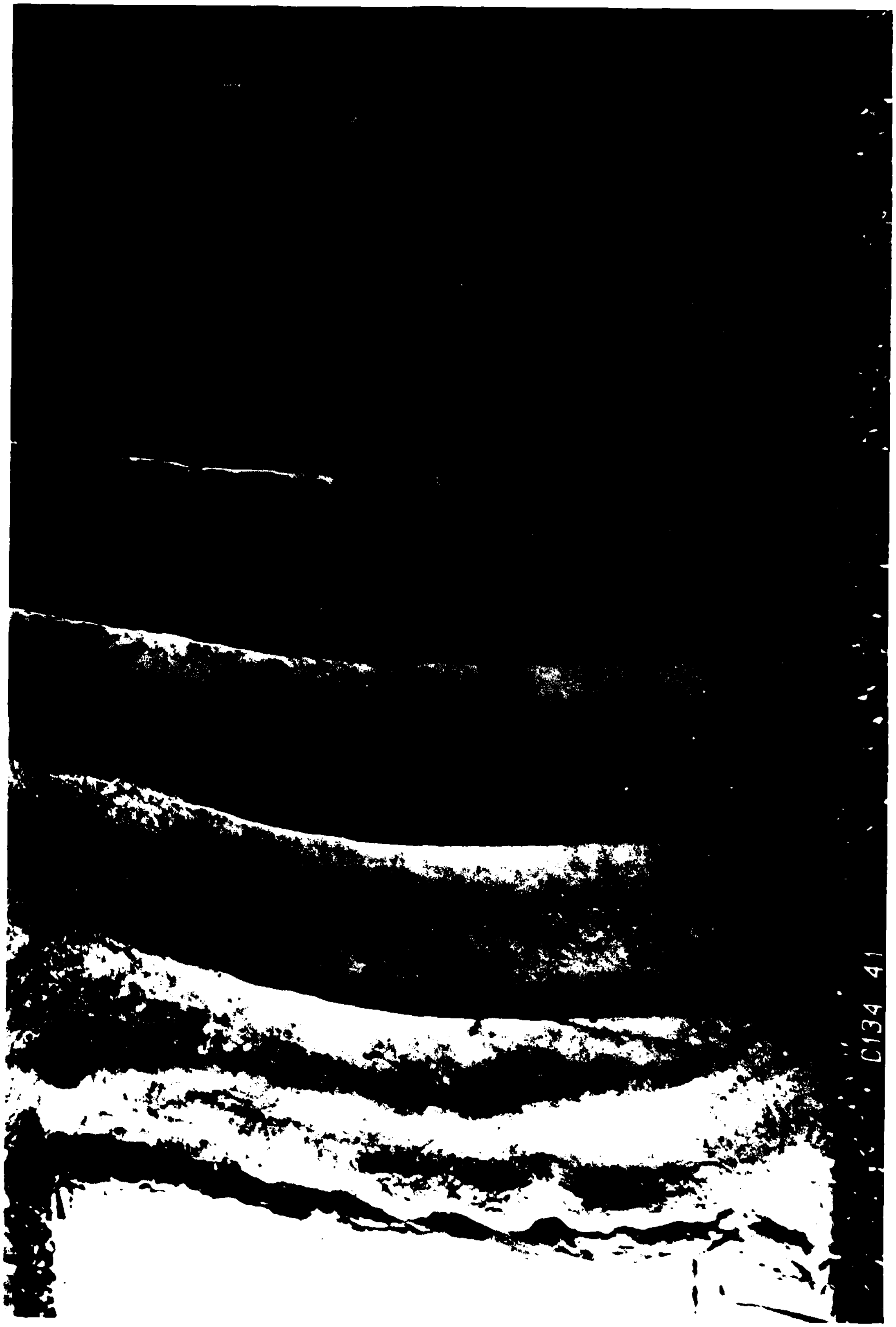
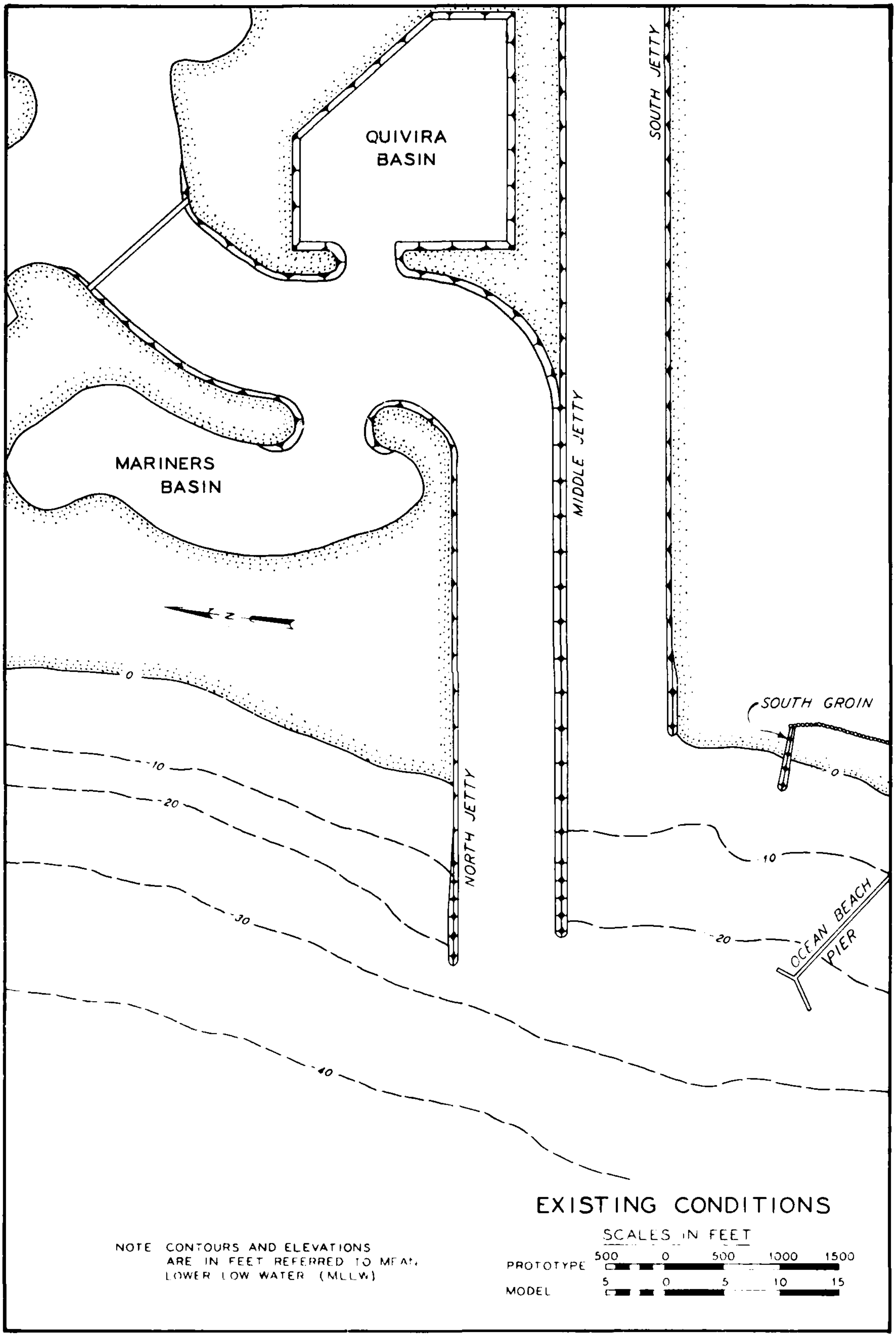


Photo 38. Typical wave patterns adjacent to the middle jetty at Ocean Beach for Plan 10B; 9-sec, 6-ft waves from west

Photo 39. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 11-sec, 3-ft waves from west

Photo 40. Typical wave patterns adjacent to the north jetty at Mission Beach for Plan 10B; 13-sec, 3-ft waves from west

Photo 41. Typical wave patterns adjacent to the middle jetty at Ocean Beach for Plan 10B; 11-sec, 3-ft waves from southwest



EXISTING CONDITIONS

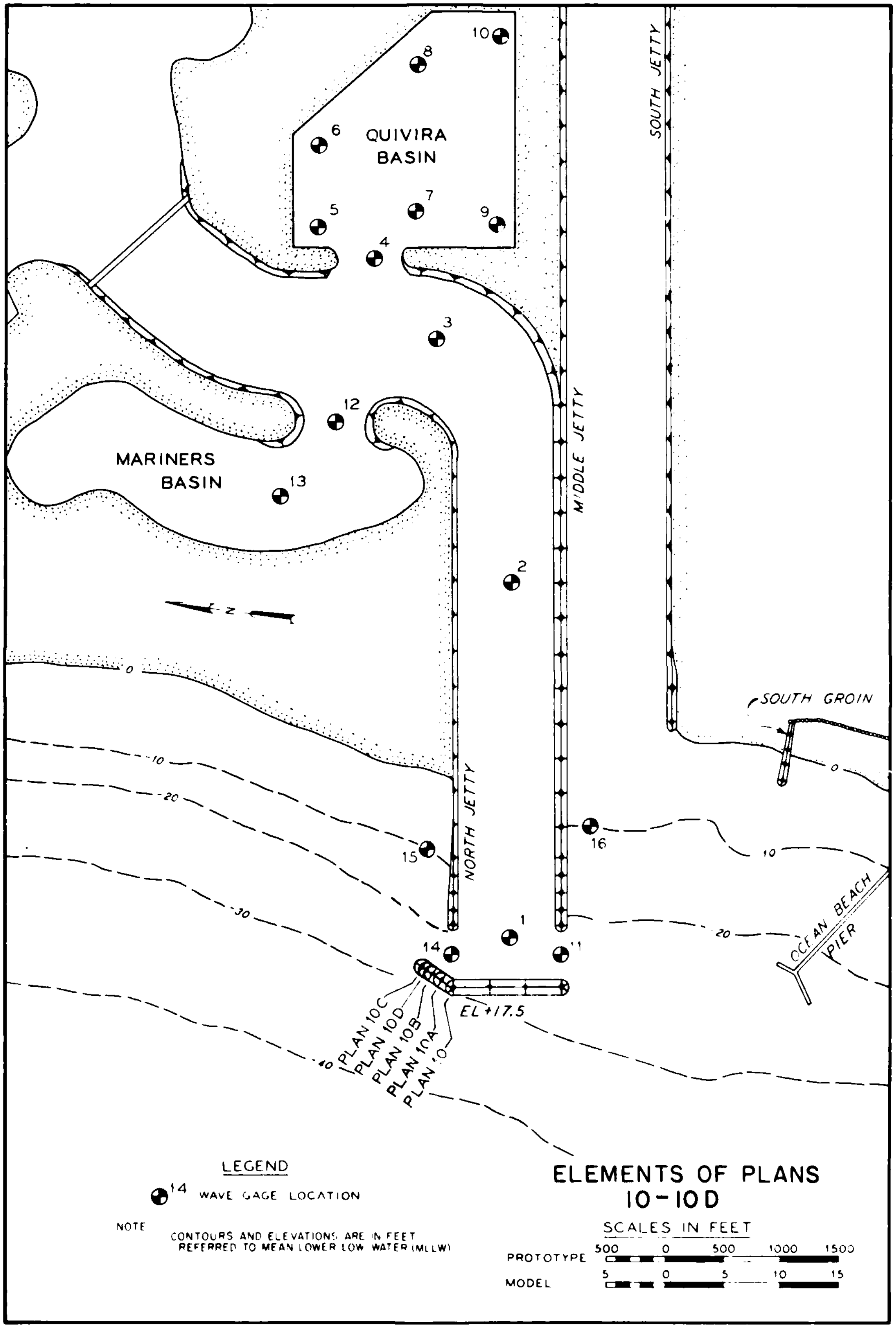
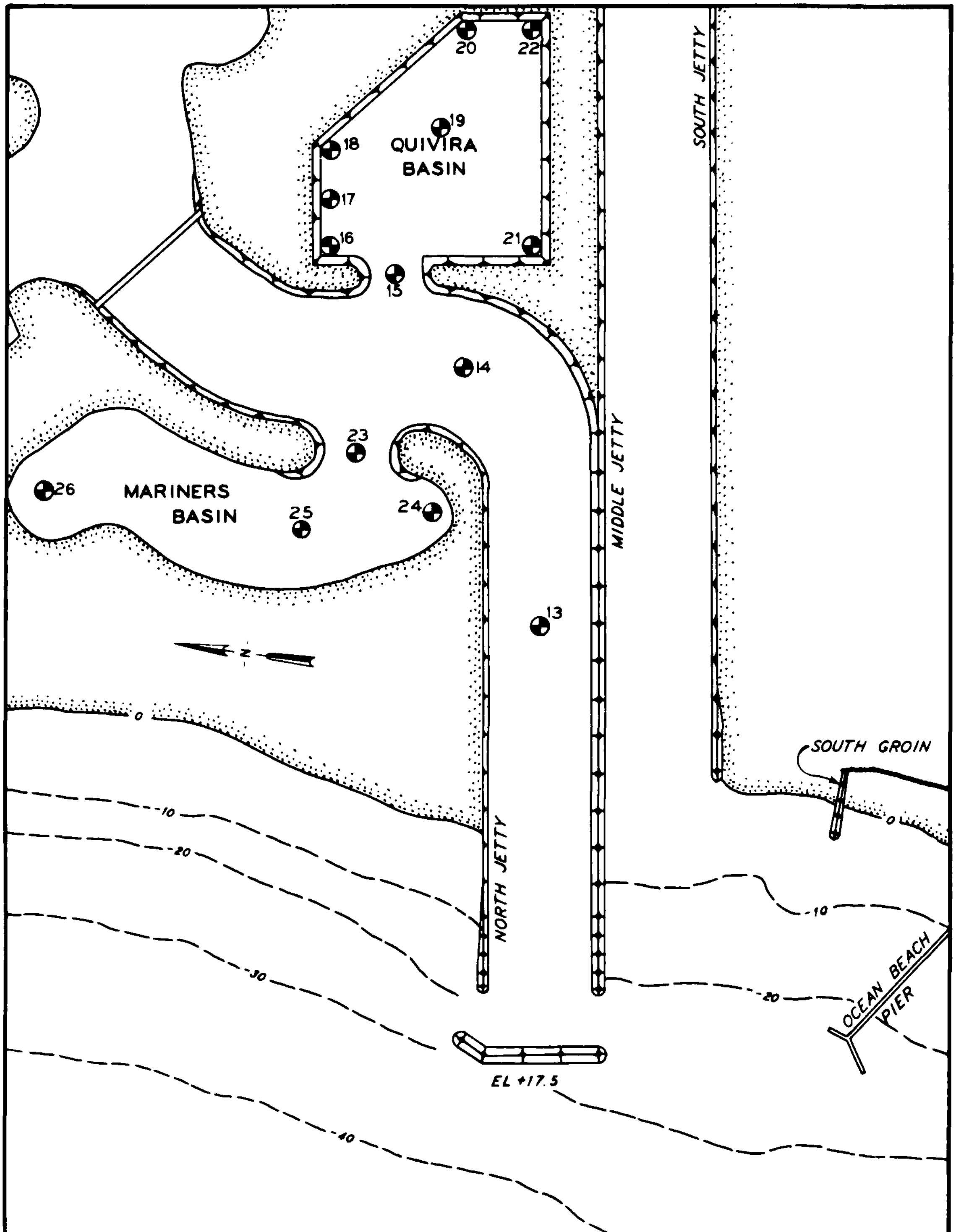

QUIVIRA BASIN
MARINERS BASIN
SOUTH JETTY
MIDDLE JETTY
NORTH JETTY
SOUTH GROIN
OCEAN BEACH PIER
EL +17.5
PLAN 10C
PLAN 10D
PLAN 10B
PLAN 10A
PLAN 10
LEGEND
WAVE GAGE LOCATION
NOTE
CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW)
ELEMENTS OF PLANS 10-10D
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15

PLATE 2



LEGEND

14 WAVE GAGE LOCATION

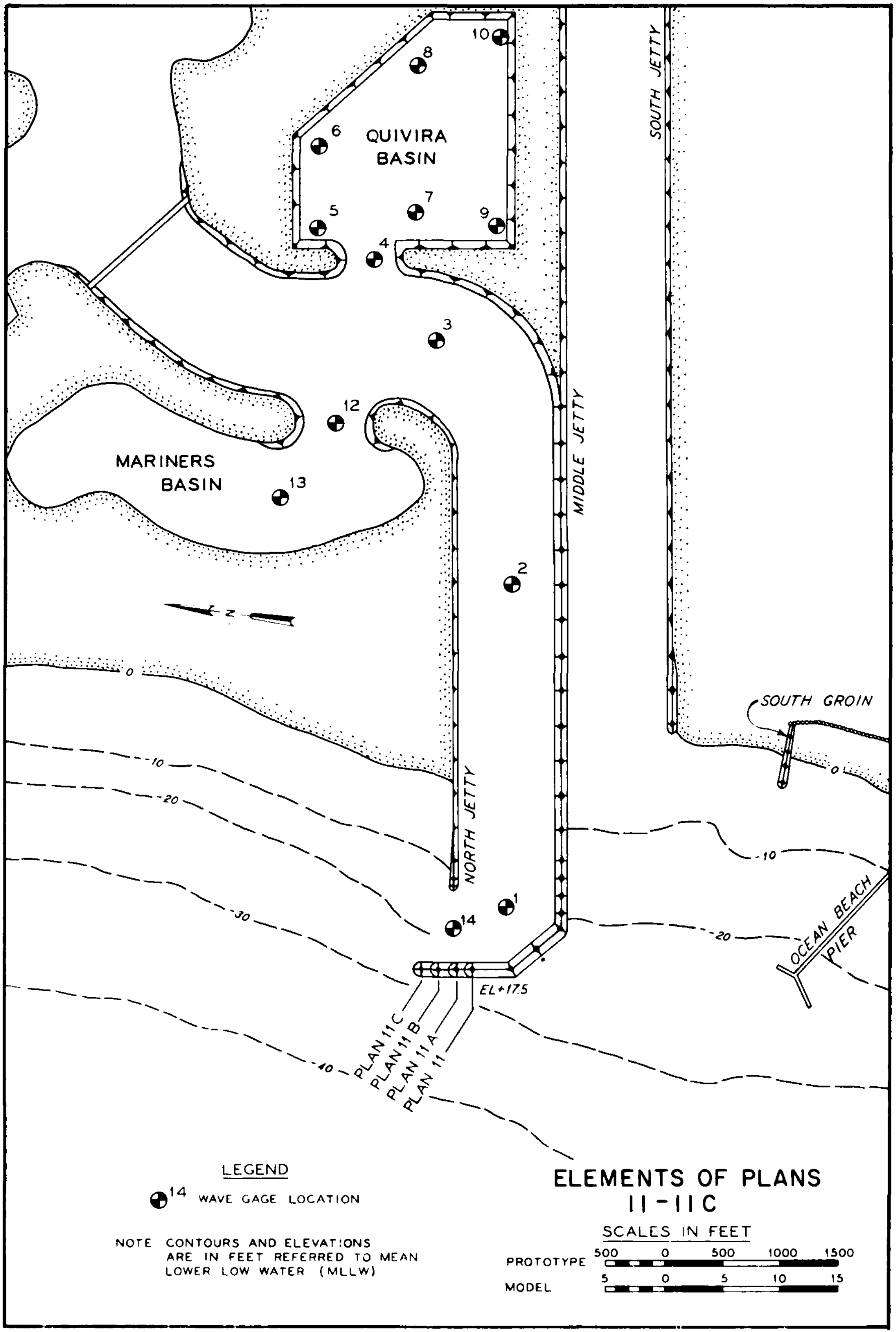
NOTE: CONTOURS AND ELEVATIONS ARE IN FEET REFERRED TO MEAN LOWER LOW WATER (MLLW)

ELEMENTS OF PLAN 10B
(LONG-PERIOD-WAVE GAGE ARRANGEMENT)

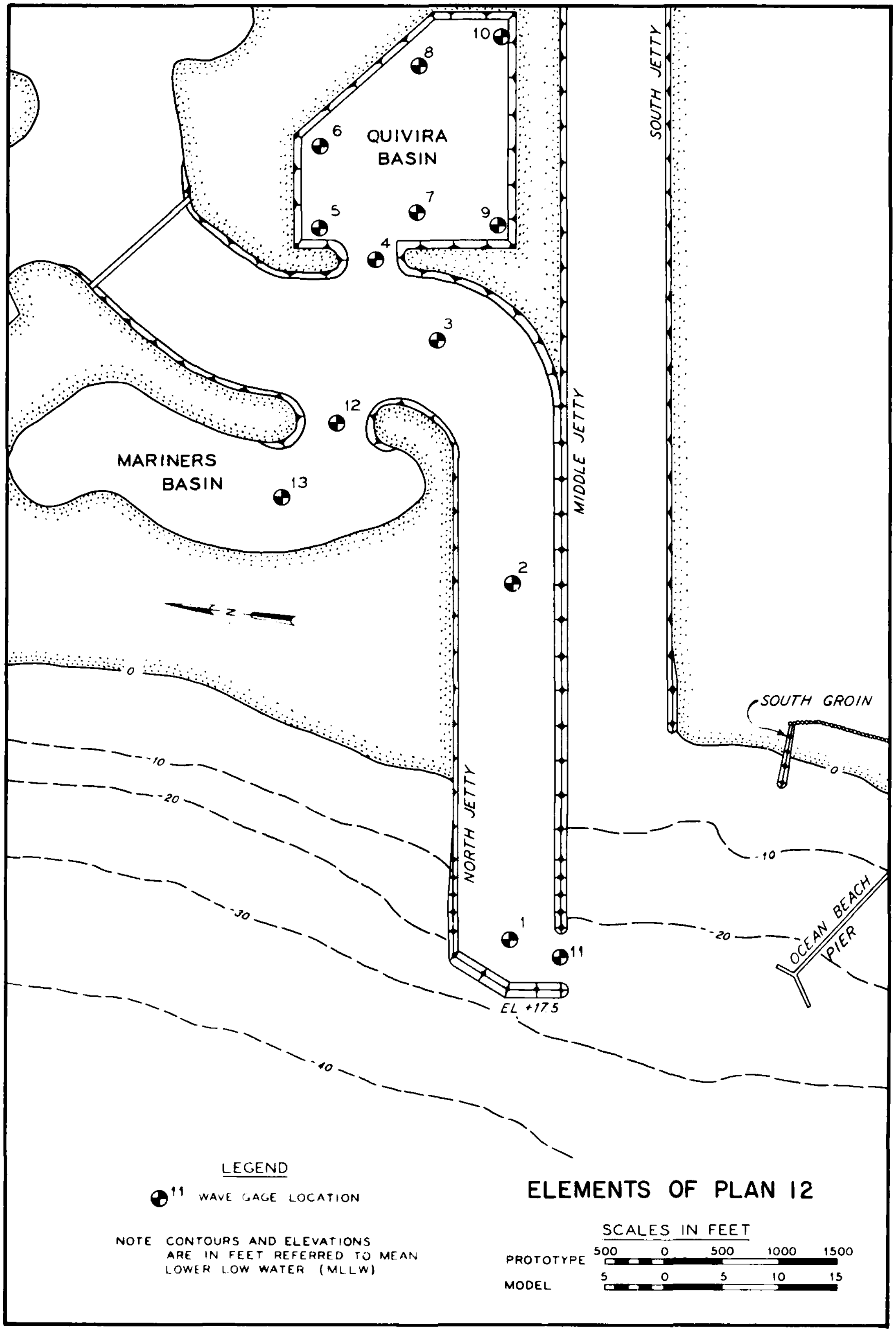
SCALES IN FEET

PROTOTYPE 500 0 500 1000 1500

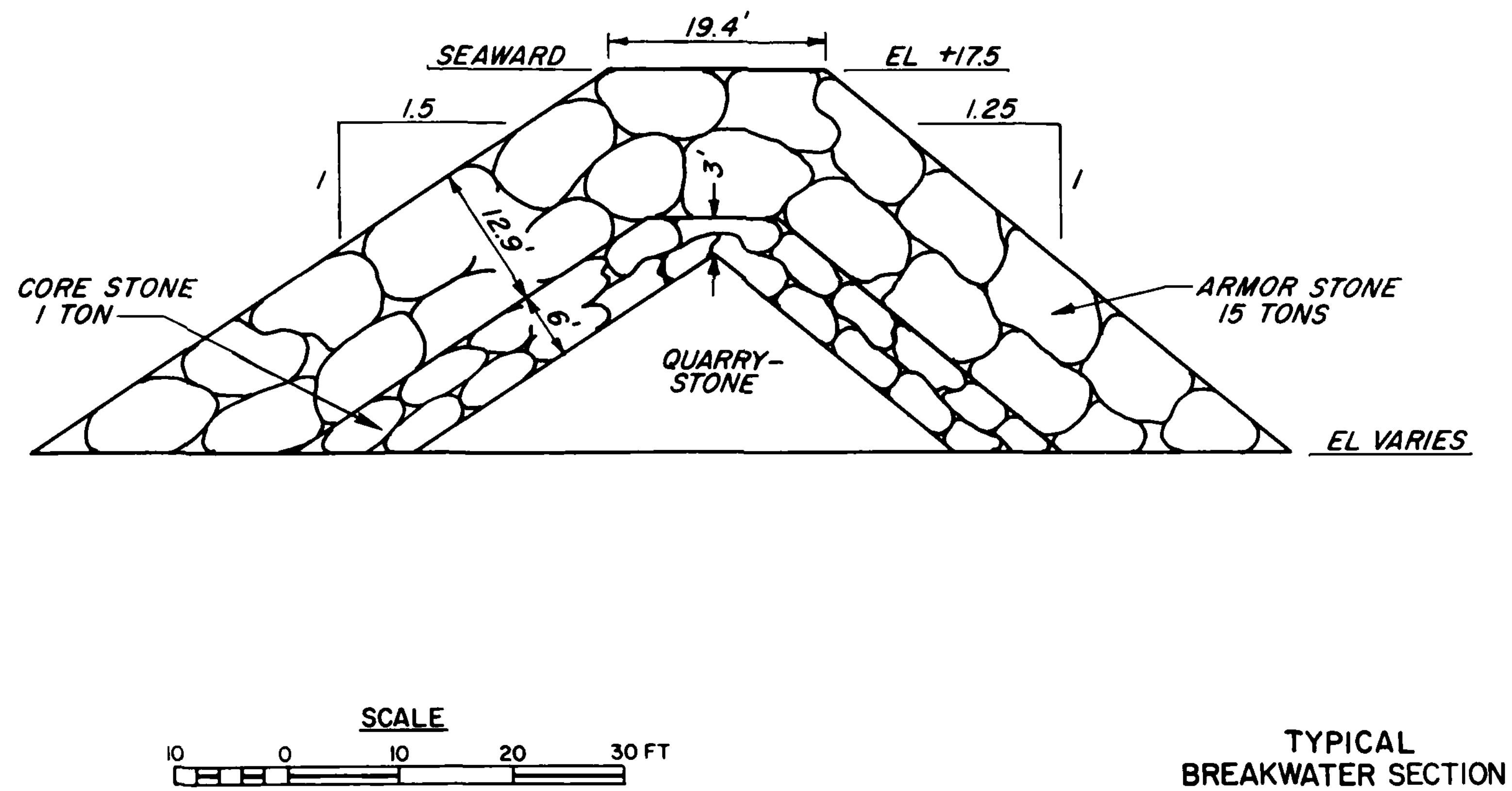
MODEL 5 0 5 10 15



QUIVIRA
BASIN
MARINERS
BASIN
SOUTH JETTY
MIDDLE JETTY
NORTH JETTY
SOUTH GROIN
OCEAN BEACH
PIER
EL+17.5
PLAN 11 C
PLAN 11 B
PLAN 11 A
PLAN 11
0
-10
-20
-30
-40
1
2
3
4
5
6
7
8
9
10
12
13
14
LEGEND
14 WAVE GAGE LOCATION
NOTE CONTOURS AND ELEVATIONS
ARE IN FEET REFERRED TO MEAN
LOWER LOW WATER (MLLW)
ELEMENTS OF PLANS
11 - 11C
SCALES IN FEET
PROTOTYPE 500 0 500 1000 1500
MODEL 5 0 5 10 15

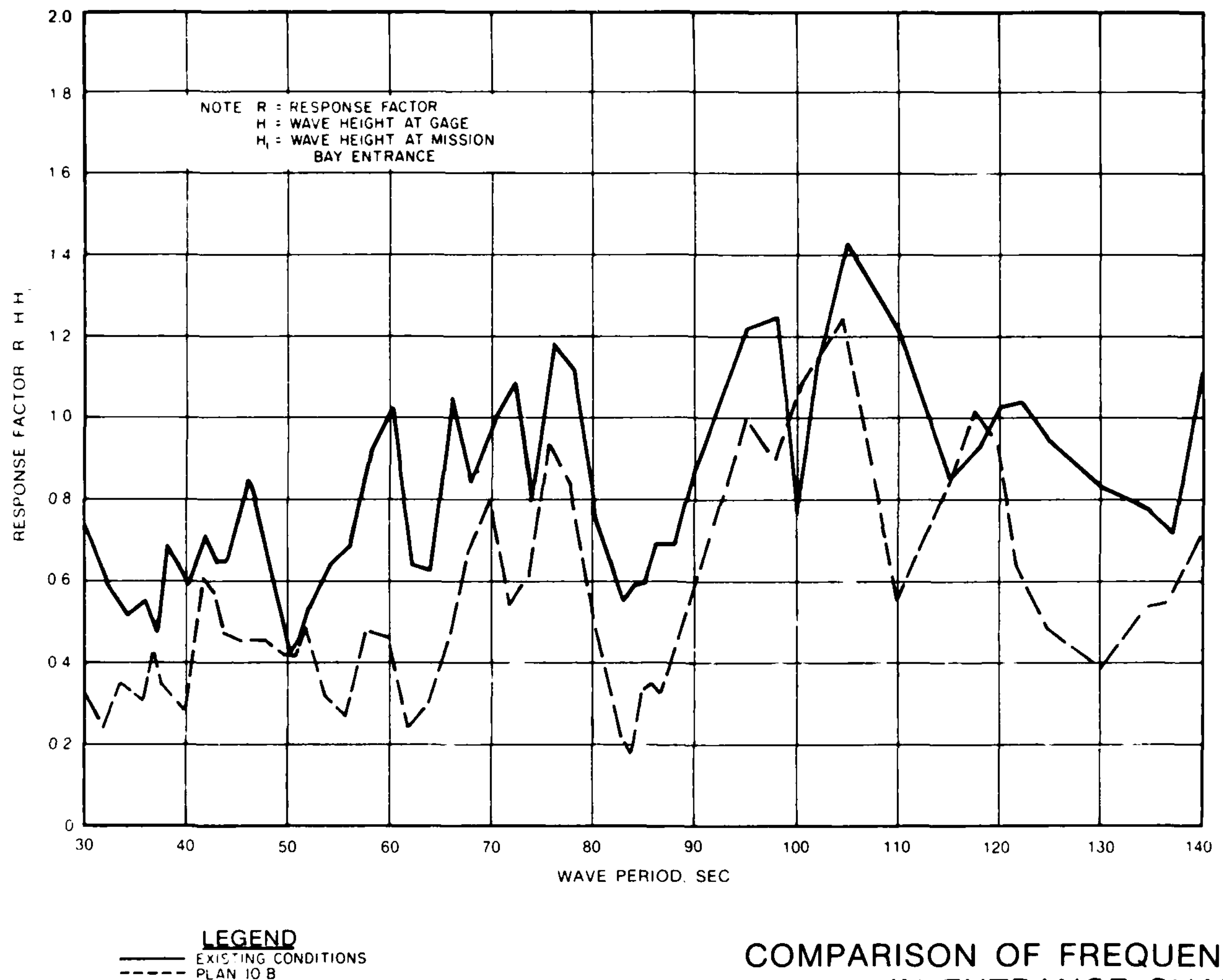


ELEMENTS OF PLAN 12

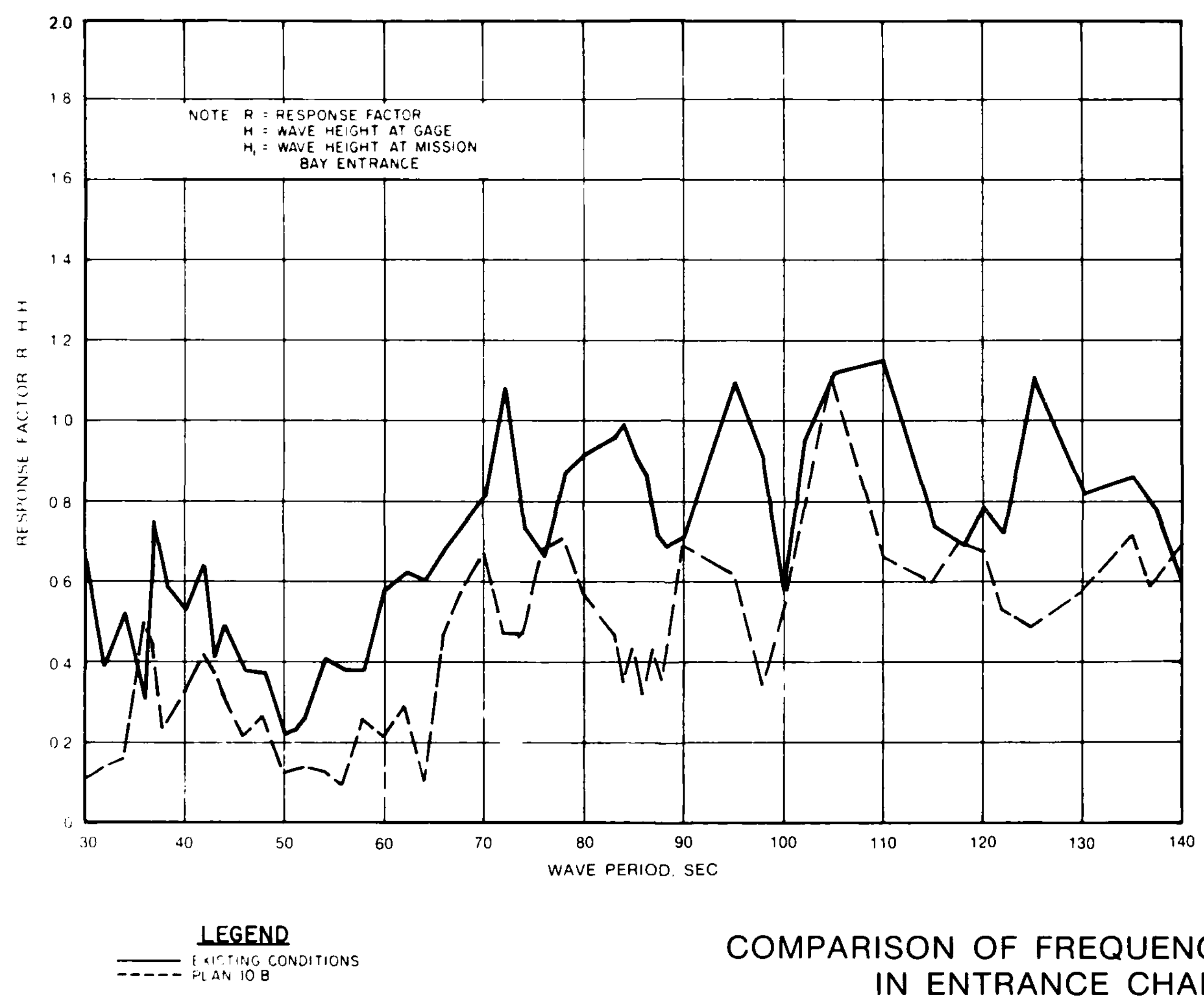


TYPICAL
BREAKWATER SECTION
PLANS 10-12

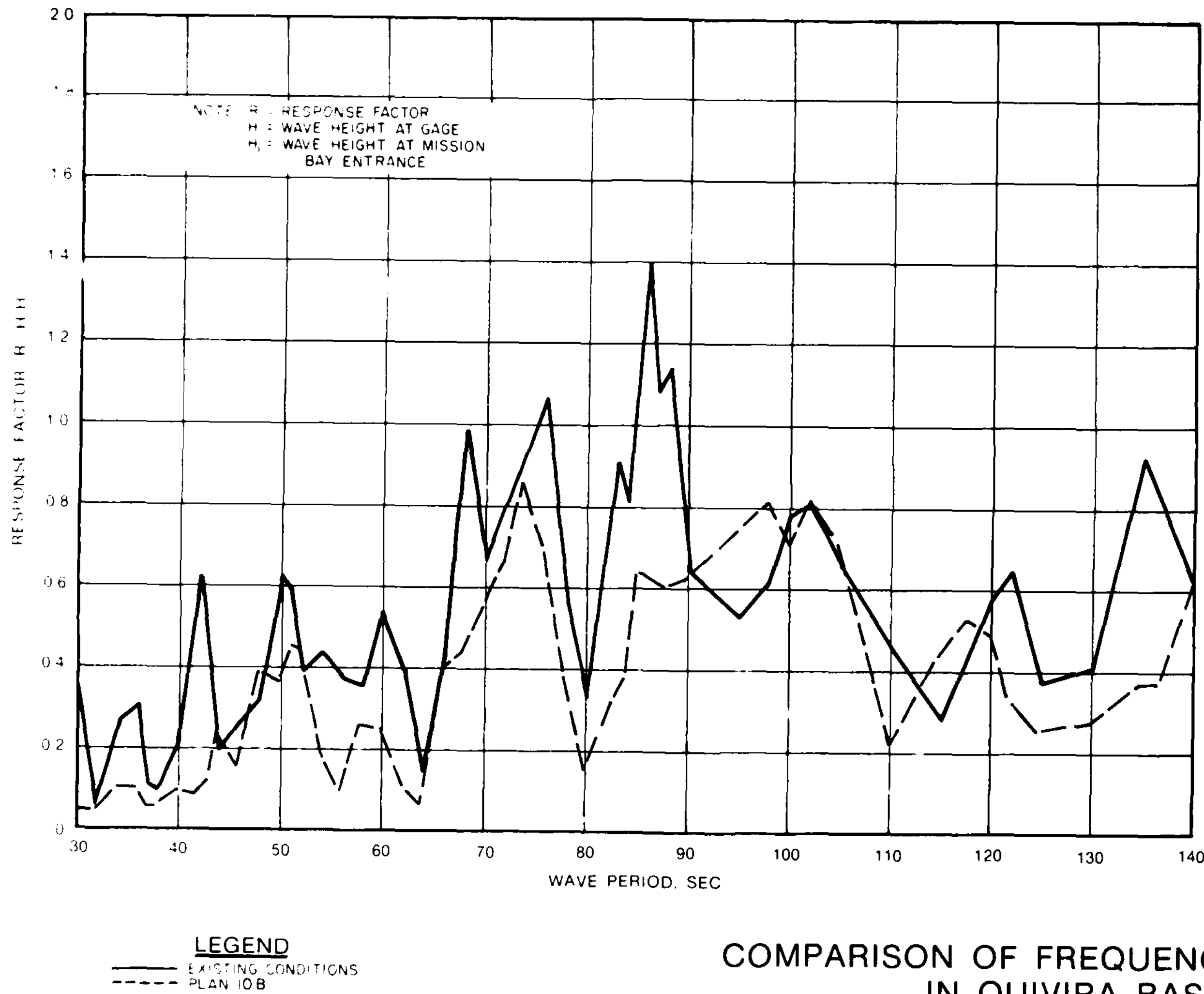
PLATE 6



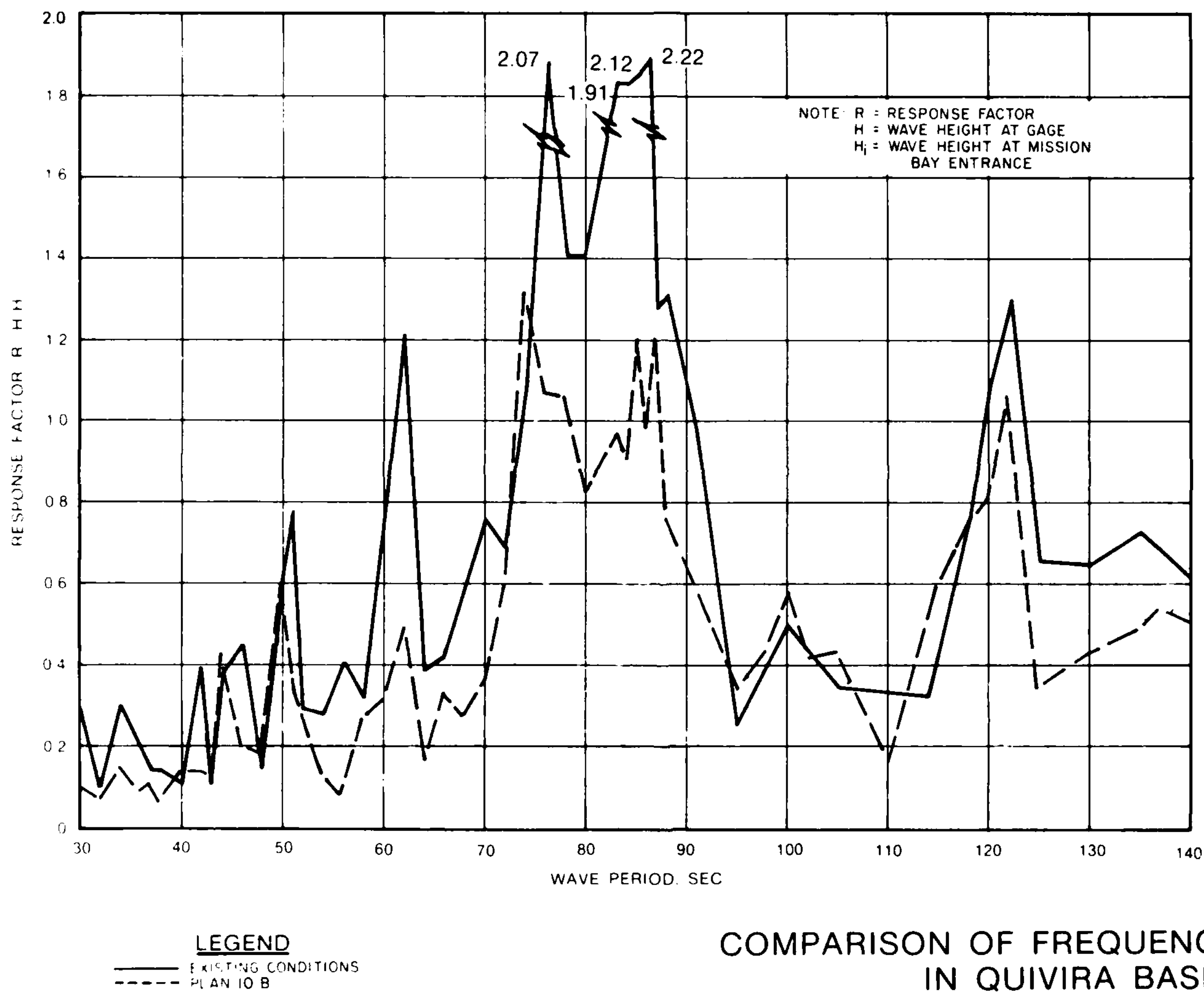
COMPARISON OF FREQUENCY RESPONSE
IN ENTRANCE CHANNEL
WAVE GAGE 13



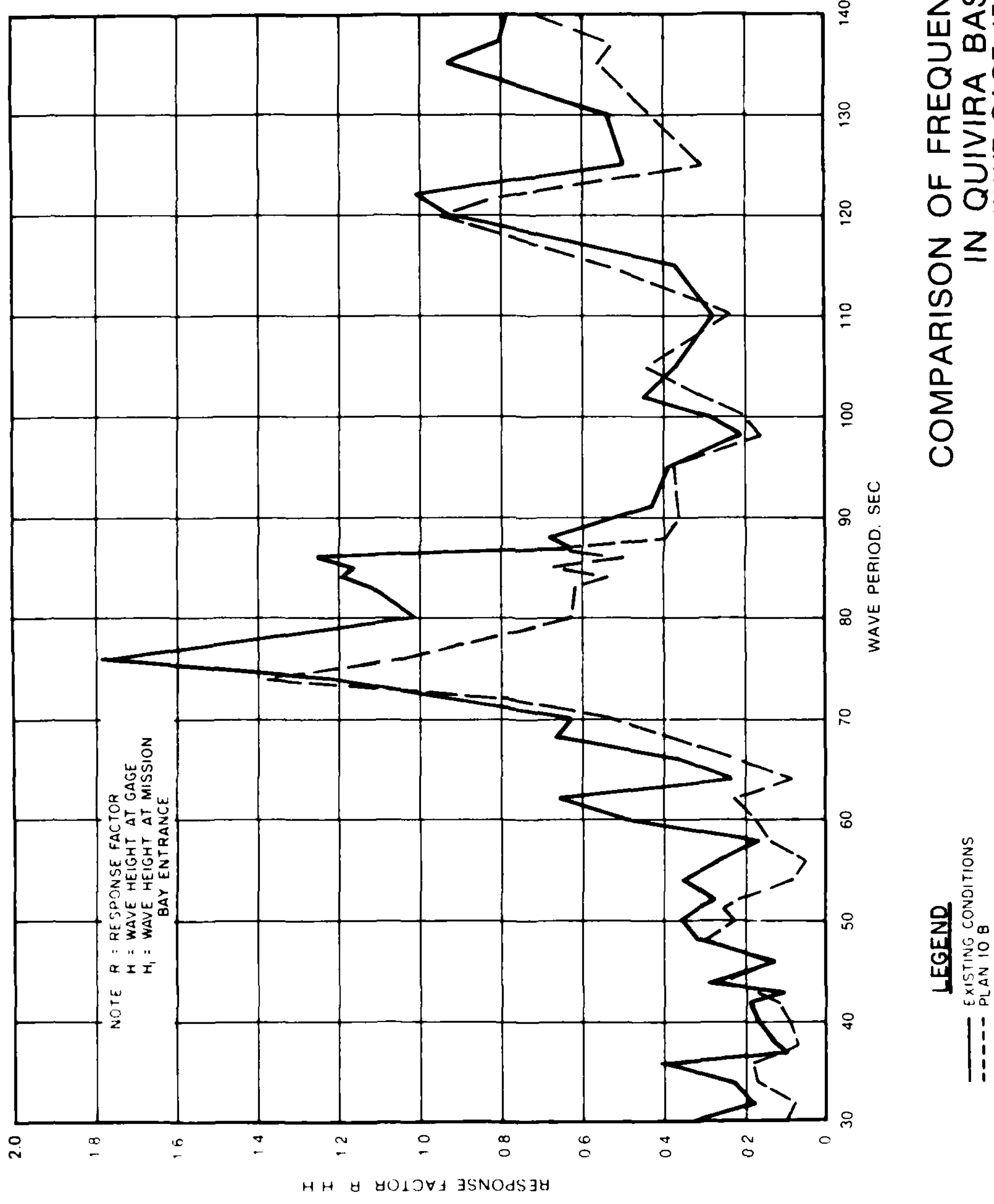
COMPARISON OF FREQUENCY RESPONSE
IN ENTRANCE CHANNEL
WAVE GAGE 14



COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 15

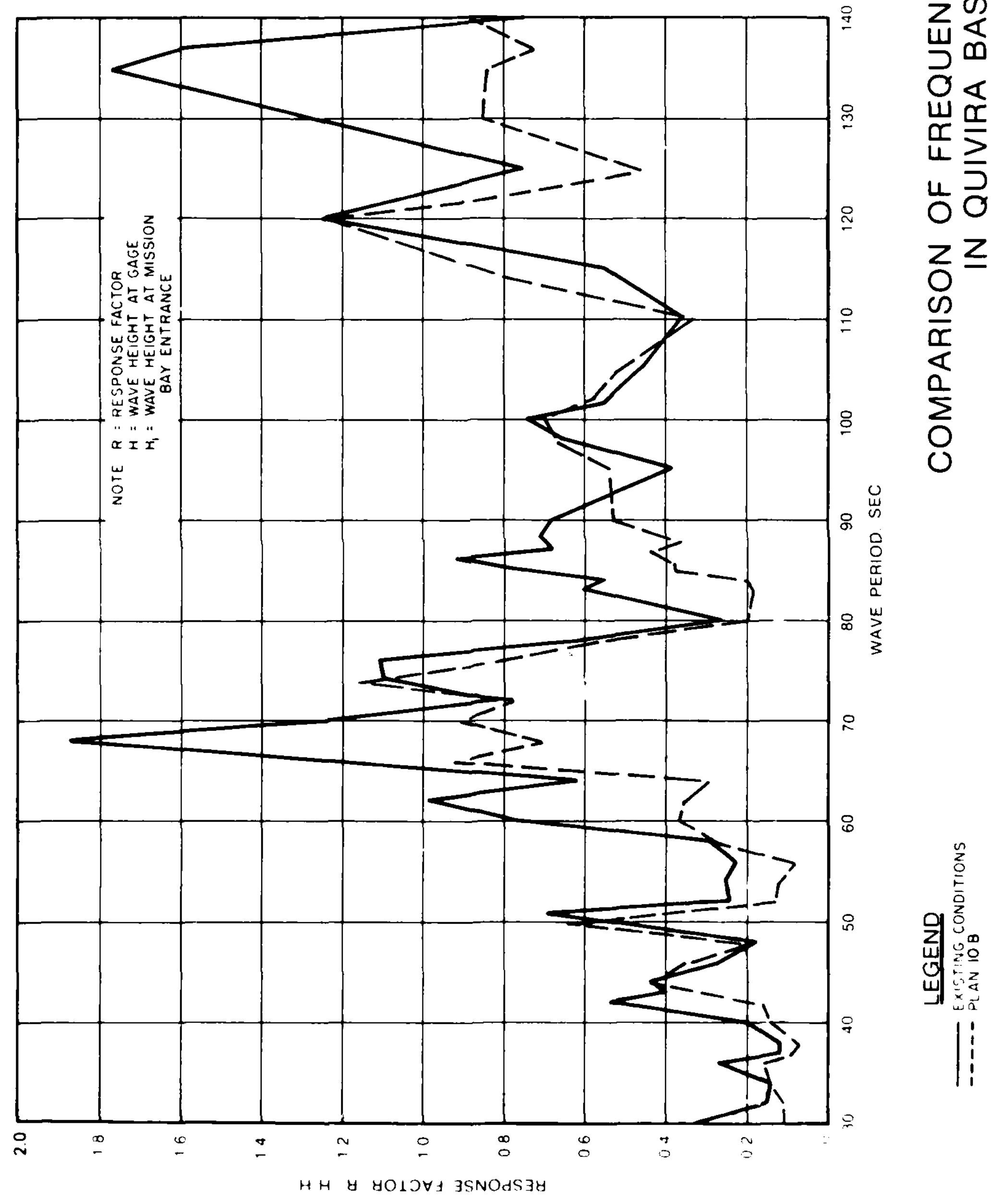


COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 16

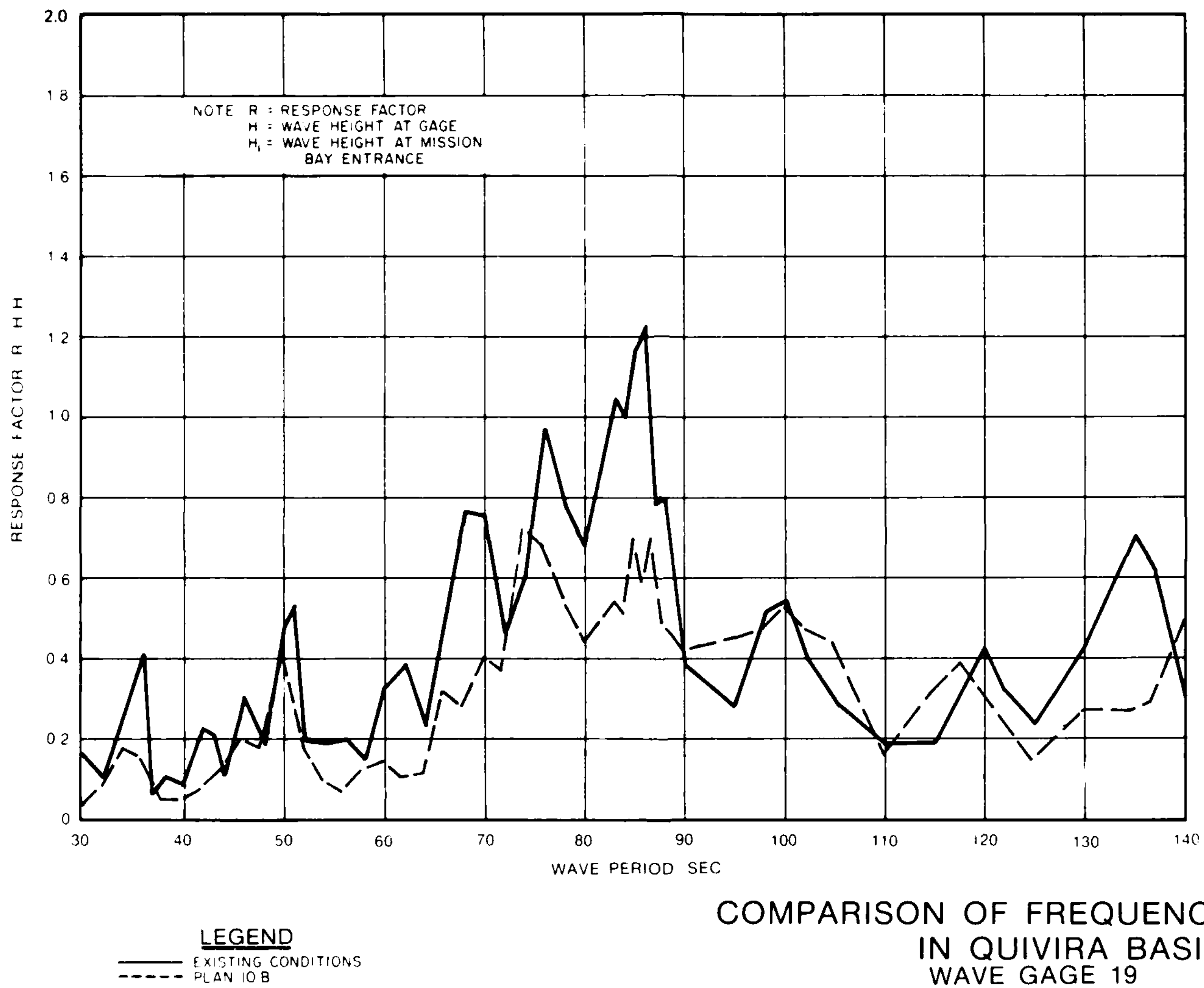


COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 17

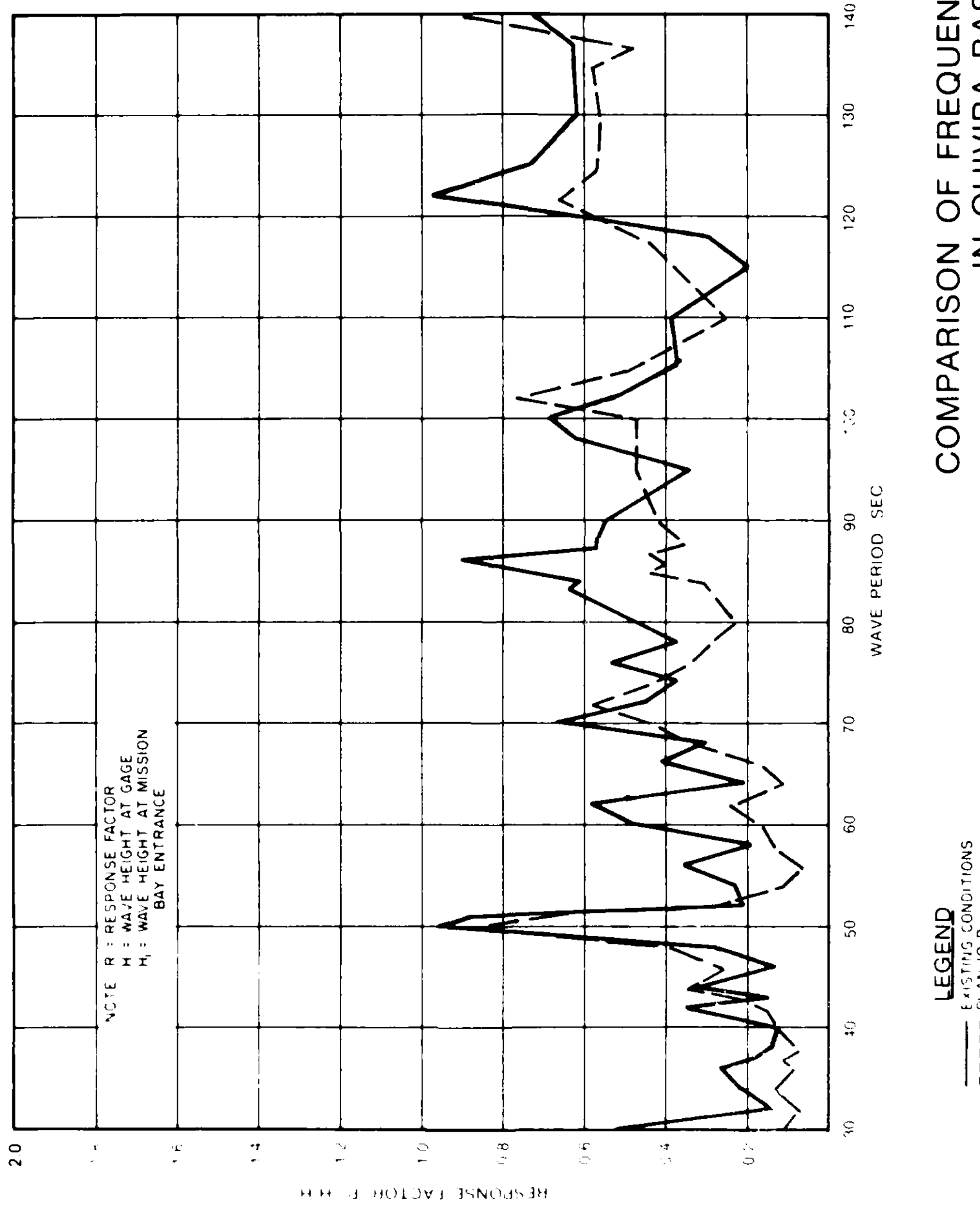
PLATE 11



COMPARISON OF FREQUENCY RESPONSE IN QUIVIRA BASIN
WAVE GAGE 18



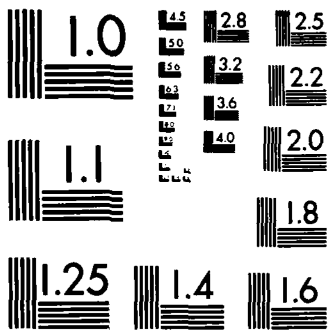
COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 19



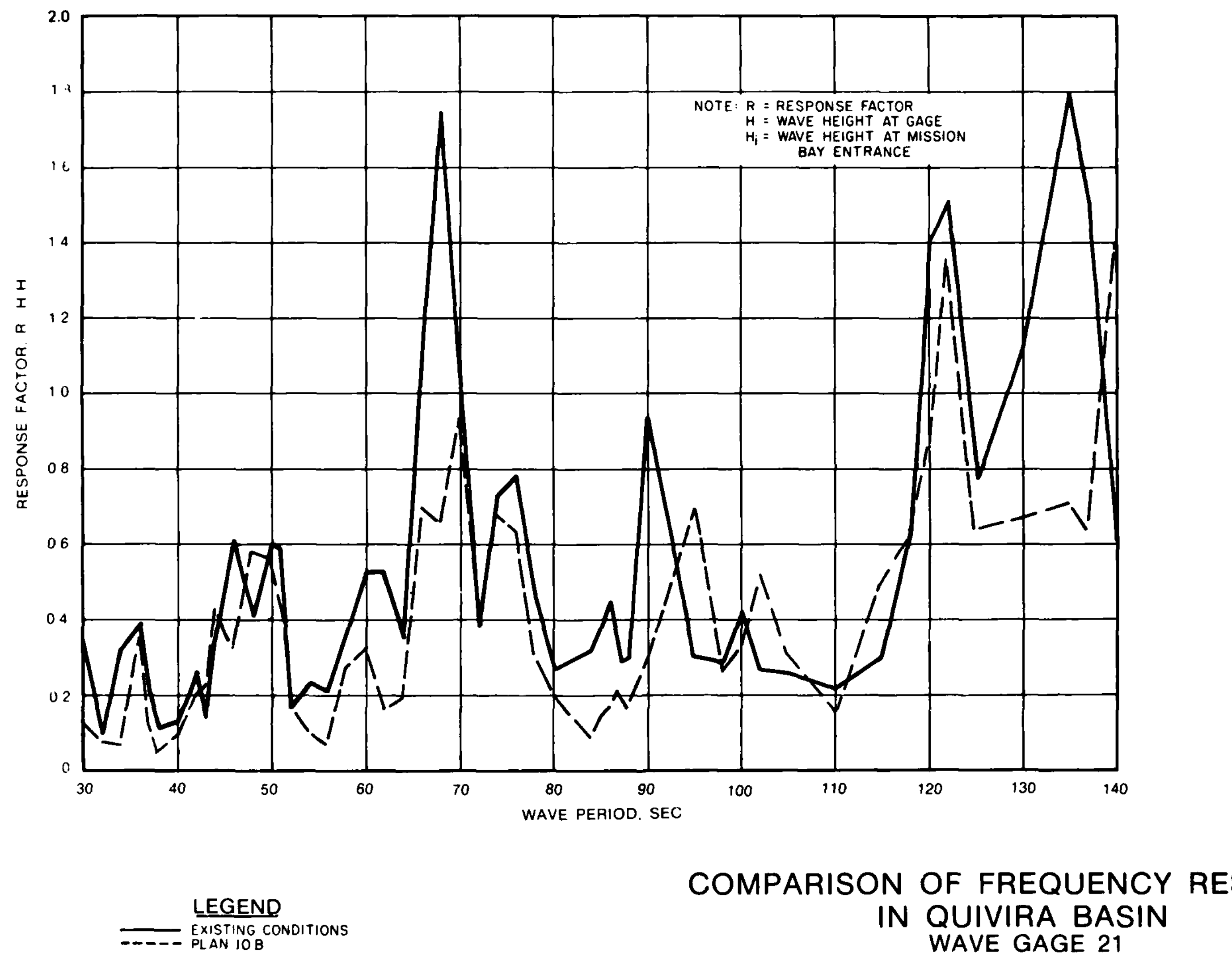
COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 20

AD-A165 134 MISSION BAY HARBOR SAN DIEGO COUNTY CALIFORNIA DESIGN FOR WAVE AND SURGE (U) COASTAL ENGINEERING RESEARCH CENTER VICKSBURG MS R R BOTTIN ET AL. DEC 85 2/2

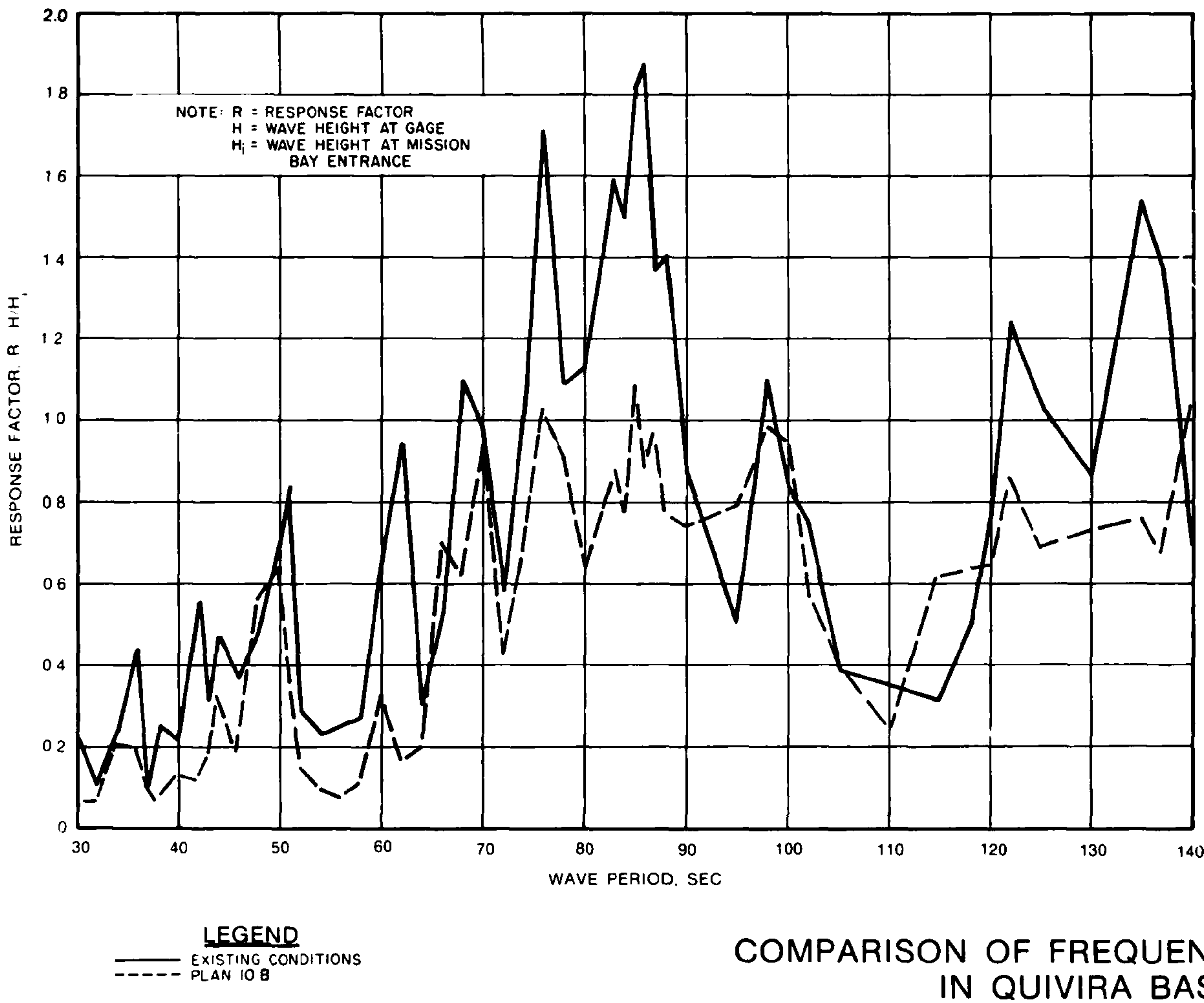
UNCLASSIFIED CERC-85-11 F/G 13/2 NL



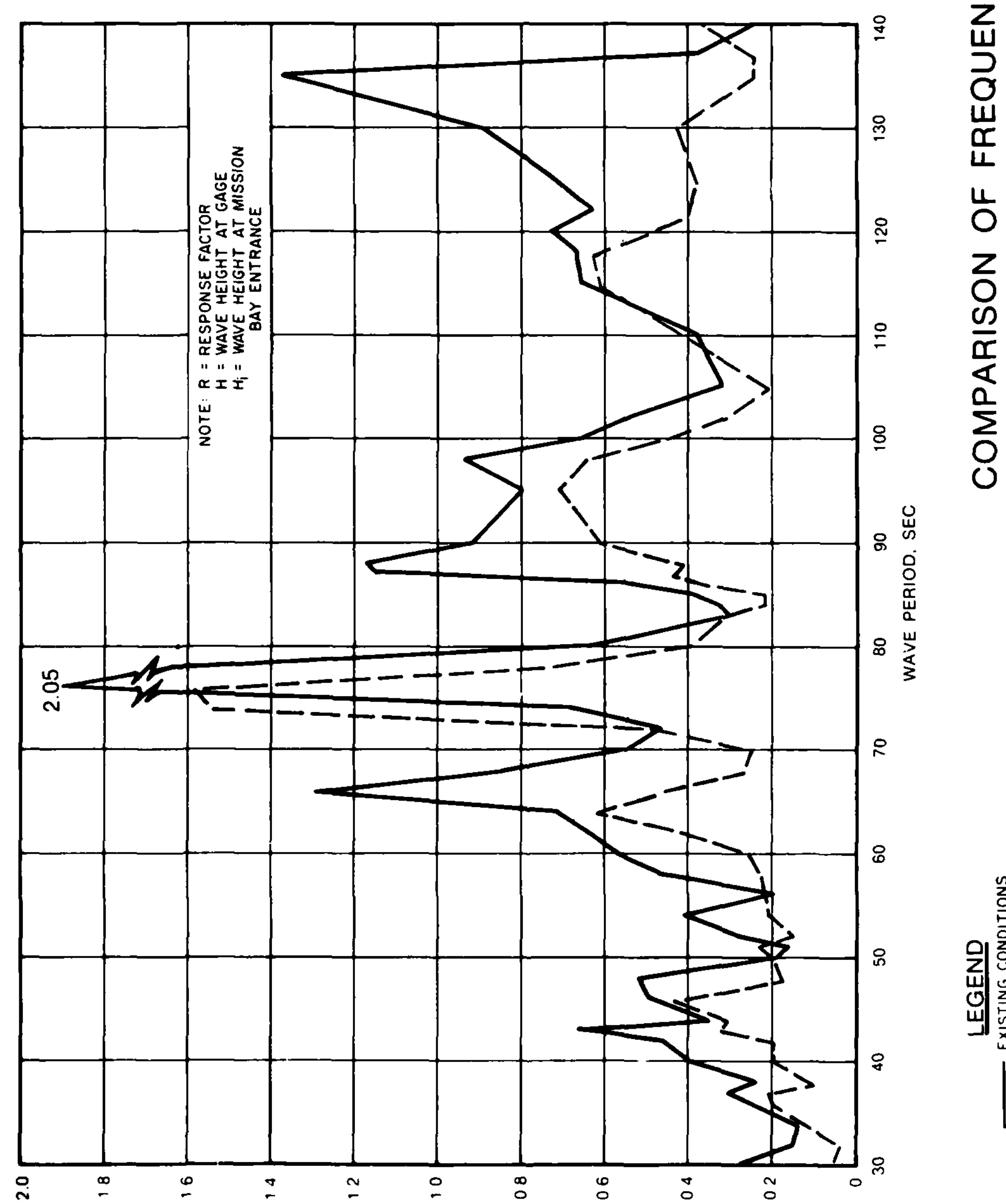
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



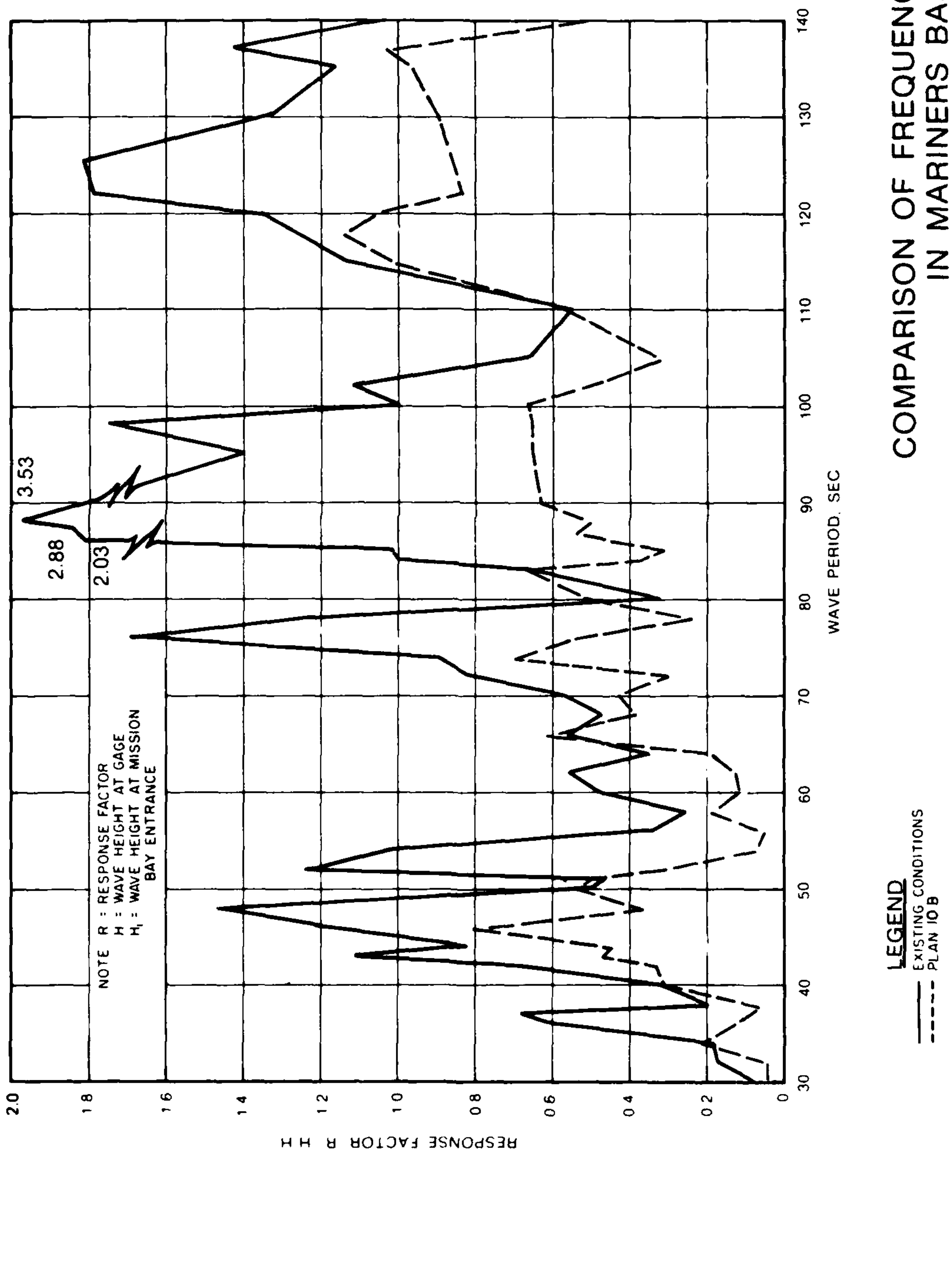
COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 21



COMPARISON OF FREQUENCY RESPONSE
IN QUIVIRA BASIN
WAVE GAGE 22

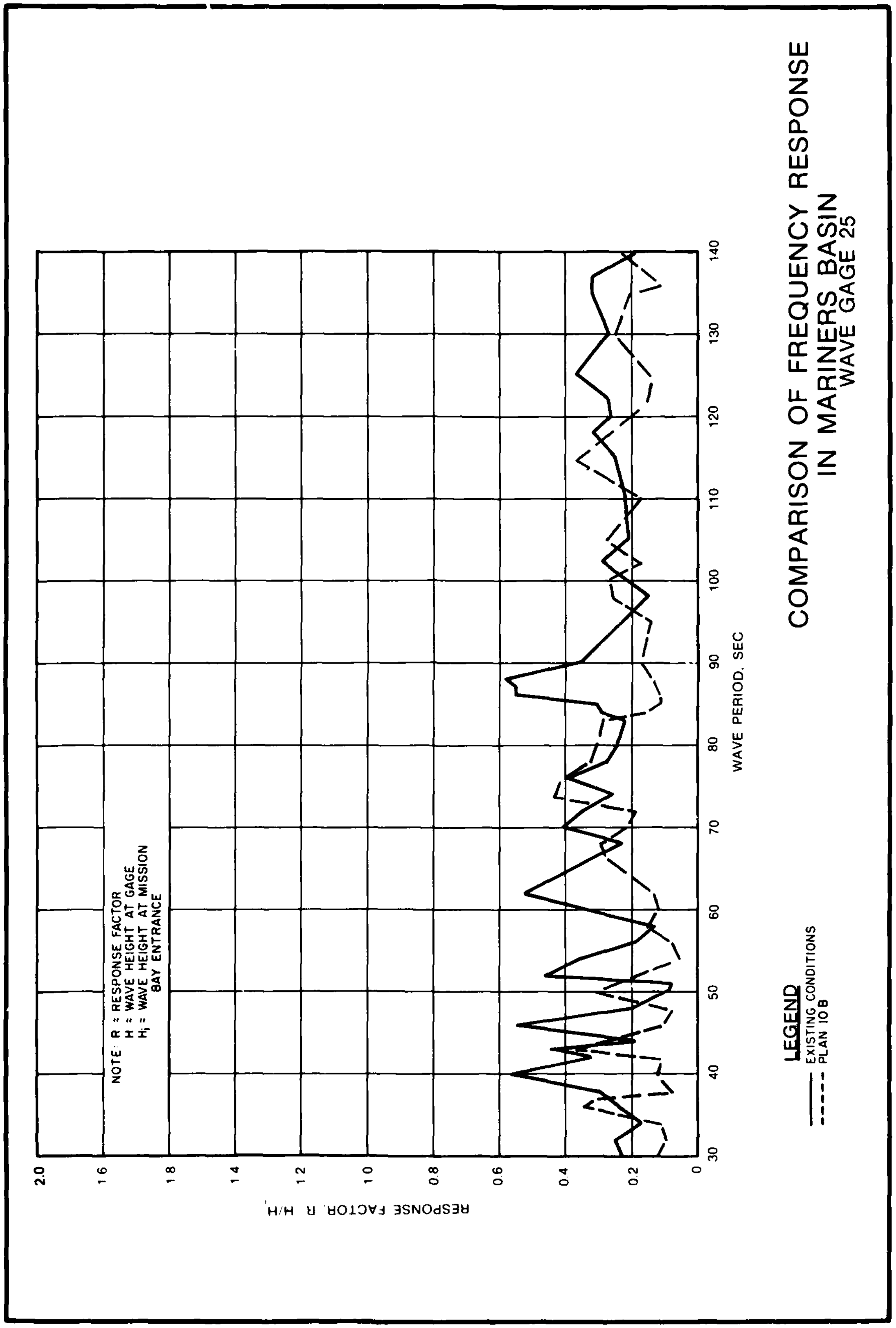


COMPARISON OF FREQUENCY RESPONSE
IN MARINERS BASIN
WAVE GAGE 23

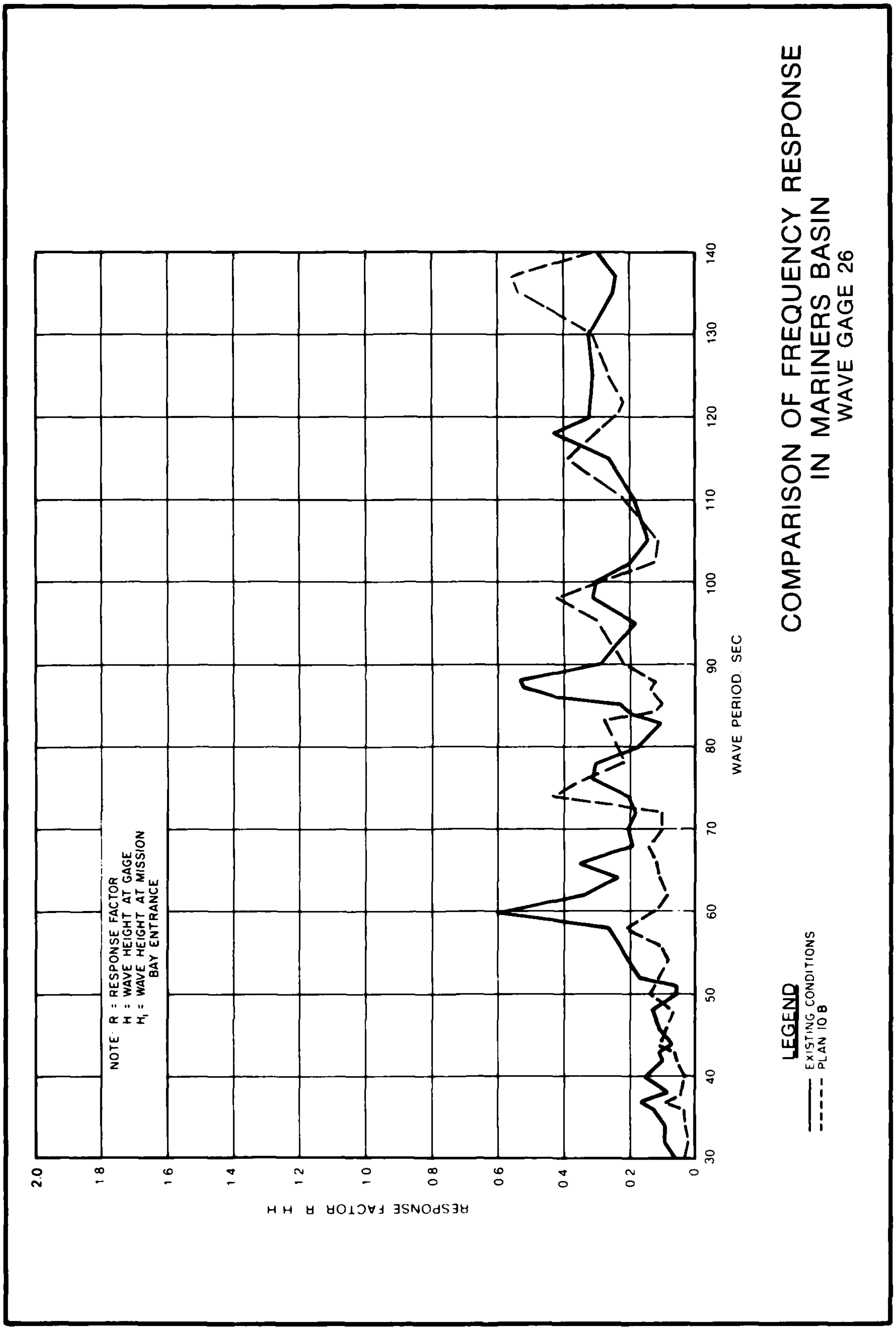


COMPARISON OF FREQUENCY RESPONSE
IN MARINERS BASIN
WAVE GAGE 24

PLATE 18



COMPARISON OF FREQUENCY RESPONSE
IN MARINERS BASIN
WAVE GAGE 25



COMPARISON OF FREQUENCY RESPONSE
IN MARINERS BASIN
WAVE GAGE 26
NOTE: R = RESPONSE FACTOR
H = WAVE HEIGHT AT GAGE
H_i = WAVE HEIGHT AT MISSION
BAY ENTRANCE
LEGEND
EXISTING CONDITIONS
PLAN 10 B
RESPONSE FACTOR R H H
WAVE PERIOD SEC
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
30
40
50
60
70
80
90
100
110
120
130
140

DTIC
FILMED
4-86
END